MENTORING, TRAINING, AND APPRENTICESHIPS FOR STEM EDUCATION AND CAREERS

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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February 15, 2018

MENTORING, TRAINING, AND APPRENTICESHIPS FOR STEM EDUCATION AND CAREERS

THURSDAY, FEBRUARY 15, 2018

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 9:11 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Barbara Comstock [Chairwoman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

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House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Mentoring, Training, and Apprenticeships for STEM Education and Careers

Thursday, February 15, 2018
9:00 a.m.
2318 Rayburn House Office Building

Witnesses

Dr. Victor R. McCrary, Vice President, Division of Research and Economic Development, Morgan State University

Dr. John Sands, Department Chair, Computer Integrated Technologies, Moraine Valley Community College and Director and Principal Investigator, Center for Systems Security and Information Assurance

Mr. Montez King, Executive Director, National Institute of Metalworking Skills

Dr. John Bardo, President, Wichita State University

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HEARING CHARTER

February 15, 2018

TO: Members, Subcommittee on Research and Technology

FROM: Majority Staff, Committee on Science, Space, and Technology

SUBJECT: Research and Technology Subcommittee Hearing:
"Mentoring, Training, and Apprenticeships for STEM Education and Careers"

The Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing titled *Mentoring, Training, and Apprenticeships for STEM Education and Careers* on Thursday, February 15, 2018 at 9:00 a.m. in Room 2318 of the Rayburn House Office Building.

Hearing Purpose:

This hearing will explore how participation in mentoring, training and apprenticeship opportunities impact science, technology, engineering, and mathematics (STEM) students and may assist in addressing the growing need for a diverse and technically trained STEM workforce. In addition, the hearing will shed light on innovative workforce training programs that keep students in the STEM pipeline and create pathways to successful STEM careers in computer science, mathematics, cyber security and other high-demand fields. The purpose of this hearing is to discover what research should be conducted and data collected in order to increase the understanding of these STEM workforce development tools, the contexts in which they are most effective, and the barriers to their expansion and application.

Witness List

- **Dr. Victor R. McCrary,** Vice President, Research and Economic Development and Professor of Chemistry, Morgan State University; Member, National Science Board and Chair, Task Force on the Skilled Technical Workforce
- **Dr. John Sands,** Department Chair, Computer Integrated Technologies, Moraine Valley Community College; Director and Principal Investigator, Center for Systems Security and Information Assurance
- **Mr. Montez King,** Executive Director, National Institute of Metalworking Skills
- **Dr. John Bardo,** President, Wichita State University

Staff Contact

For questions related to the hearing, please contact Catherine Johnson of the Majority Staff at 202-225-6371.

Chairman SMITH. [Presiding] The Subcommittee on Research and Technology will come to order. Without objection, the Chair is authorized to declare recesses of the committee at any time.

Good morning to everyone here, and welcome to today's hearing entitled, "Mentoring, Training, and Apprenticeships for STEM Education and Careers."

Before I recognize myself for my opening statement, let me explain to all present that our Chairwoman, Barbara Comstock, is stuck in traffic and I don't think is even across the bridge yet, so we're going to go on and start. We have other individuals caught up in traffic as well. All that is probably compounded by the fact that we're starting an hour earlier than normal because this is a day where a lot of Members are leaving town in a few hours.

I still think it's important for us to get started, and as soon as Barbara Comstock, the Chairwoman, arrives, she'll have an opening statement. As soon as Mr. Lipinski arrives, he'll have a statement as the Ranking Member. And I'm going to go on and give my opening statement just so we can get started and introduce you all, but at various points we might be interrupted as individuals arrive and have opening statements.

This hearing continues the Science Committee's work on STEM. The *STEM Education Act of 2015* updated the definition of STEM to include computer science. And the *2017 American Innovation and Competitiveness Act* strengthened external stakeholders' roles in setting STEM priorities.

Most recently, the Committee and the full House approved several bipartisan bills aimed at boosting students' interest in STEM subjects and opportunities for our military veterans and for women and underrepresented minorities, starting in kindergarten.

Apprenticeships, mentoring, and on-the-job training are proven ways to meet workforce needs. I look forward to hearing from our witnesses about the potential for using these workforce development methods to boost STEM education and careers.

According to the National Science Board's most recent Science and Engineering Indicators report, the number of U.S. jobs that require science, technology, engineering, math, and computer skills has grown nearly 34 percent in the past decade. STEM workforce demand is forecast to increase steadily for years to come. Filling our STEM workforce needs, from certificate-level technical occupations to Ph.D.'s, is essential for our economic competitiveness.

STEM jobs are growing in every sector of our economy, from the shop floors in advanced manufacturing, to computer programming for our huge service industry sector, to cybersecurity for every public and private computer network. According to a recent report from Brookings, half of all STEM jobs are available to workers without a four-year college degree, and these jobs pay a wage ten percent higher than jobs with similar educational requirements. Filling the workforce pipeline with qualified STEM workers at every level is crucial for our future economic prosperity.

The innovative workforce training programs in which our witnesses are involved can provide new opportunities for STEM education and training and encourage young people to pursue STEM-based careers. Successful workforce development programs extend beyond the four walls of classrooms and laboratories. Partnerships

between industry and academia can create new ways for young people to pursue STEM careers and boost formal education and training with on-the-job work experiences.

[The prepared statement of Chairman Smith follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
February 15, 2018

Media Contacts: Thea McDonald, Brandon VerVelde
(202) 225-6371

Statement by Chairman Lamar Smith (R-Texas)

Mentoring, Training, and Apprenticeships for STEM Education and Careers

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Chairman SMITH. That concludes my opening statements, and I'm going to check to see what we want to do on the minority side. You want to just wait for Lipinski or do you want to——

Ms. BONAMICI. Mr. Chairman, if we could please wait for Mr. Lipinski——

Chairman SMITH. Okay.

Ms. BONAMICI. —to deliver the opening statement when he arrives.

Chairman SMITH. Okay.

Ms. BONAMICI. Thank you.

Chairman SMITH. We'll——

Ms. BONAMICI. I yield back.

Chairman SMITH. —wait for the gentleman from Illinois to arrive, but I'd like to go on and introduce our witnesses so we'll be ready to start.

Our first witness today is Dr. Victor McCrary, Vice President of Research and Economic Development and Professor of Chemistry at Morgan State University. In this role, Dr. McCrary and his team focus on developing a university-wide research ecosystem, increasing external support for the faculty research, and championing an entrepreneurial culture among faculty and students. Dr. McCrary is also a member of the National Science Board and Chair of the Task Force on the Skilled Technical Workforce. With the NSB, Dr. McCrary recently proposed the blue-collar STEM initiative to explore the technical skills required by the Nations' workforce which do not necessitate pursuing a traditional four-year college degree.

Dr. McCrary earned a Bachelor of Arts in chemistry from the Catholic University of America and a Master of Science and executive master's of engineering from the University of Pennsylvania. He also earned a Ph.D. in physical chemistry from Howard University.

Dr. Sands is our second witness, and he is the Department Chair of Computer Integrated Technologies at Moraine Valley Community College. Dr. Sands also serves as the Director and Principal Investigator for the Center for Systems Security and Information Assurance, where he and his team study the technology workforce needs both nationally and in the local Chicago metropolitan region in Ranking Member Lipinski's district.

Dr. Sands earned a Bachelor of Arts in communications from Chicago State University and a master of arts in human performance and testing from Governor State University. He also earned his Ph.D. in education from Colorado State University.

Our third witness today is Mr. Montez King, Executive Director of the National Institute of Metalworking Skills (NIMS), developing national standards and competency-based credentials in manufacturing trades. In this role, Mr. King is responsible for overseeing the administration, programs, and strategic plan of the organization.

Prior to joining NIMS, Mr. King served as Training and Technology Manager for Magna International, one of the world's largest OEM automotive parts manufacturers. In October 2017, he was appointed to the President's Task Force on Apprenticeship Expansion. Mr. King began his career at Teledyne Energy Systems as a Machinist Apprentice and spent over 25 years advancing into manage-

ment positions. He holds a Maryland State machinist journeyman's certificate, a Bachelor of Science in information technology, and a Master of Education degree in adult education from the University of Phoenix.

Our final witness today is Dr. John Bardo, President of Wichita State University. Wichita State's Innovation Campus and applied learning initiatives have drawn positive national attention because the partnerships forged with local and international companies including Airbus, Dassault Systemes, and Koch Industries. The university has a long history of working with industry through its National Institute of Aviation Research and National Center for Aviation Training. Dr. Bardo's academic interests involve the relationships between higher education, the economy, and quality of life.

He received a bachelor's degree in economics from the University of Cincinnati and a master's degree in sociology from Ohio University. He also earned a Ph.D. in sociology from Ohio State University and attended the Institute for Educational Management at Harvard.

And we welcome you all, appreciate your expertise. And as I mentioned when I introduced myself to you a few minutes ago, it's nice to have a hearing on such an interesting subject, that's a very positive subject, that's a bipartisan subject, and that's important to the future of America.

I'm going to hold off for a second and get a read for how far away Chairwoman Comstock is before we proceed.

Ms. BONAMICI. Mr. Lipinski's in Rayburn, so he's almost here.

Chairman SMITH. Okay. We're getting close. Since we're already off to a pretty good start, I think we're just going to recess for about five minutes and wait for the Chairwoman and the Ranking Member to arrive. They'll each have an opening statement, and then we'll go straight to your testimony. So we stand in recess for about five minutes.

[Recess.]

Chairwoman COMSTOCK [PRESIDING]. Good morning, and my apologies. There was an accident on G.W. Parkway—I have the benefit of being close by, but sometimes also there are some disadvantages.

So this morning's hearing will explore how participation in mentoring, training, and apprenticeship opportunities impact STEM students and may assist in addressing the growing need for a diverse and technically trained STEM workforce. The purpose of this hearing is to identify what STEM workforce development programs should be further examined and what statistics are needed to increase our understanding of these tools, the contexts in which they are most effective, and the barriers to their application and expansion.

About 20 percent of all jobs in the U.S. economy require some level of STEM training, and that will grow. Those occupations are projected to grow about nine percent over the next decade, faster than any other employment category. In order to meet this demand, Congress needs to make informed decisions on what are the most impactful and innovative tools to address the STEM skills gap and build up America's skilled technical workforce.

A majority of these technical STEM jobs do not require a bachelor's degree. In many cases, these good positions, such as computer programmers, information technology support, and nurses, require two-year degrees, occupational licenses, or certifications. Technical STEM jobs are often among the best-paying and most stable jobs available to individuals with sub-baccalaureate education. By supporting innovative workforce development programs for STEM careers like those our witnesses are part of, we not only increase the students' economic opportunities and security, but also our nation's.

To ensure the United States' competitiveness in the global economy, we must leverage this hard work and ingenuity of women and men of all ages, education levels, and backgrounds to grow America's technical workforce.

I look forward to building on the progress this Committee has already made through the *INSPIRE Women Act*, which was signed into law by the President last year, and the recently House-passed *Building Blocks of STEM*, to encourage and grow the number of young women and under-represented minorities in STEM fields also. Reaching these groups at a young age and motivating them to stay in the STEM fields is extremely important, but we must also ensure we support programs aimed at keeping women and under-represented minorities in the STEM pipeline and advancing in STEM careers.

There are recognized models from across the country and the world that demonstrate how apprenticeships, mentoring, and on-the-job training are tools used by many different industries to address skills gaps. One thing is clear: The most successful programs are an integration of academia, technical training, and hands-on work experience.

I know as I go throughout my district and I meet with employers who need employees, they really want to be able to bring them in and train them to their workplace, and so I think what we're talking about here today really fits that needs gap. So I look forward to hearing from our witnesses today about the programs they lead and how they are working with industry to meet the diverse and growing needs for a STEM capable workforce. Thank you.

[The prepared statement of Chairwoman Comstock follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
February 15, 2018

Media Contacts: Thea McDonald, Brandon VerVelde
(202) 225-6371

Statement by Chairwoman Barbara Comstock (R-Va.)

Mentoring, Training, and Apprenticeships for STEM Education and Careers

Chairwoman Comstock: This morning's hearing will explore how participation in mentoring, training and apprenticeship opportunities impact STEM students and may assist in addressing the growing need for a diverse and technically trained STEM workforce. The purpose of this hearing is to try to identify what STEM workforce development programs should be further examined and what statistics are needed to increase our understanding of these tools, the contexts in which they are most effective, and the barriers to their application and expansion.

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Chairwoman COMSTOCK. And I now recognize the Ranking Member, Mr. Lipinski, for his opening statement.

Mr. LIPINSKI. Thank you, Chairwoman Comstock. I don't know if you know, but I was racing you to get in. You passed me on G.W. Parkway, and I saw you again on the 14th Street Bridge, but somehow you made it in here before me so I apologize for being late. We were both stuck in the same traffic jam on the parkway. So I want to thank Chairman Smith for holding fort here and Ms. Bonamici also.

The National Science Board recently released its biannual Science and Engineering Indicators report. My biggest takeaway from the report is that we're falling behind. China has learned from our economic success, which we've achieved in large part through investments in science and innovation. China and others are aggressively investing in research and development and in their own STEM workforces. Meanwhile, we're tapping the brakes.

This is not the time to be complacent about our standing as a global economic leader. Other countries are nipping at our heels, and we must take meaningful action before it is too late. While creating financial incentives and lowering costs for businesses may help provide a boost, fiscal policy alone will not keep our economy strong. To ensure our long-term economic health, we must continue to actively invest federal dollars in the long-term foundation on which our economy is built: research and development and human capital.

In today's increasingly technological and data-driven economy, a strong STEM workforce is critical for growth and global competitiveness. When workers are equipped with the technical skills that industry needs, companies are able to innovate, increase production, expand, and create new jobs. This virtuous cycle is interrupted when employers cannot find workers with the skills they need. This is where we find ourselves today.

The so-called STEM skills gap is not new. While we can debate the precise cause and scope of the gap, its effects are undeniable. The demand for STEM skills is growing and rapidly evolving as employers continually update their business models to stay ahead of the competition. And our education system has generally been slow to respond and adapt to the changing economy. As a result, businesses have struggled to find qualified workers. The skills gap is worse in some industry sectors than others but in many cases, it is dragging down productivity.

There are good examples of innovative approaches to career-focused STEM education around the country such as the NSF-funded Advanced Technological Education program at Moraine Valley Community College in my district, run by one of today's witnesses, Dr. Sands.

I'm also encouraged by companies such as Accenture and IBM. They are piloting an old model of workforce development: the apprenticeship, in new fields like cybersecurity and customer service. But we'll need far more innovative programs like these to meet growing demand.

The issue of STEM workforce development is a particularly important one to me. Chicago is unique among major U.S. cities and the degree to which the economy strong in both service and manu-

facturing jobs. These sectors are increasingly driven by technology, automation, and data analytics, so the demand for STEM skills is high.

I look forward to hearing from our witnesses today their thoughts on mentoring, apprenticeships, and other innovative strategies for workforce development and whether they should be more widely adopted in new industry sectors and geographic regions. As Ranking Member of this Committee—Subcommittee I'm particularly interested in hearing ideas on the role federal science agencies can play in increasing coordination between industry and educational institutions.

We need to close the STEM skills gap in the near term, but I think it is just as important to create an agile STEM workforce that can respond to changing needs over the long term. Our future depends on it.

Thank you, and I yield back the balance of my time.

[The prepared statement of Mr. Lipinski follows:]

OPENING STATEMENT
Ranking Member Daniel W. Lipinski (D-IL)
of the Subcommittee on Research and Technology

House Committee on Science, Space, and Technology
Subcommittee on Research and Technology
"Mentoring, Training, and Apprenticeships for STEM Education and Careers"
February 15, 2018

Thank you, Chairwoman Comstock, for holding this hearing and all of the witnesses for being here this morning. The National Science Board recently released its biennial Science and Engineering Indicators report. My biggest takeaway from the report is that we are falling behind. China has learned from our economic success, which we have achieved in large part through our investments in science and innovation. China and others are aggressively investing in research and development and in their own STEM workforces. Meanwhile, we are tapping the brakes.

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As Ranking Member of the Research and Technology Subcommittee, I am particularly interested in hearing ideas on the role federal science agencies can play in increasing coordination between industry and educational institutions. We need to close the STEM skills gap in the near term, but I think it is just as important to create an agile STEM workforce that can respond to changing needs over the long term. Our future depends on it.

Thank you. I yield back the balance of my time.

[The prepared statement of Ranking Member Eddie Bernice Johnson:]

OPENING STATEMENT

Ranking Member Eddie Bernice Johnson (D-TX)

House Committee on Science, Space, and Technology
Subcommittee on Research and Technology
"Mentoring, Training, and Apprenticeships for STEM Education and Careers"
February 15, 2018

Thank you Chairwoman Comstock and Ranking Member Lipinski for holding this hearing, and good morning and welcome to our esteemed panel of witnesses. This country needs STEM workers at all skill levels – from the factory floor to cutting edge research laboratories. In this Committee we often focus on the more advanced degrees and skill levels. Today we will be examining the large and diverse blue-collar STEM workforce that powers our economy.

Technology and automation are rapidly changing the nature of the blue-collar workforce, as well as the skills that a worker needs to qualify for a well-paying job and career. Every sector of our economy is experiencing an increased demand for workers with STEM skills. In November of last year, I co-hosted a panel on Blue Collar STEM at an event in the Capitol Visitors Center. We were pleased to have Dr. McCrary participate in that panel as well.

One of the major themes to emerge from that panel was the need for greater coordination between educators and employers. Panelists stressed the need for employers to provide input on what skills they require and to contribute monetarily to training. There was also discussion on holding employers accountable for hiring students once they graduate from their training programs. Another major theme was the persistence of the stigma against vocational training. These are highly-skilled, good paying jobs, but we clearly need to do better at educating the public at large that these are attractive careers for themselves and their children.

Much of today's panel will focus on these same themes, especially on the role apprenticeships can play in developing of a skilled technical workforce. We have an excellent panel that represents a range of stakeholders and thinkers on these questions, and I look forward to the discussion.

Last June, President Trump issued an Executive Order on expanding apprenticeships in which he required every federal agency to submit to OMB a list of programs that are designed to promote skills development and workforce readiness. Agencies must also submit data on the effectiveness of these programs, or carry out new evaluations if the data do not already exist.

Madame Chairwoman, a number of agencies within our jurisdiction have programs of this type. I hope we can follow up with a hearing, or perhaps a bipartisan letter to these agencies to learn about the progress they've made since last summer in identifying and evaluating their workforce development programs.

With that, I thank the witnesses for being here this morning to share your insights, and I yield back.

Statements submitted by Representative Randy Hultgren on behalf of STEM Scholar Eiken:

- Research on how the growth mindset is applied would be helpful in mentoring. My school district talked to us a lot about a growth, mindset, grit, and individual determination. There is even a program called Advancement via Individual Determination (AVID) that teaches these principles. It is helpful to learn about these, but their application should be researched more, since some teachers and counselors struggle with teaching and implementing these ideas.
- Studying how early career exposure, such as high school internships, might be positive reinforcement for students to continue in STEM. A STEM-related high school internship is rare and competitive, but if studies show that it can encourage and motivate students to stay in STEM, it might encourage businesses to open up more opportunities to serious high school students. This would also give businesses experience working with future scientists and engineers.
- I grew up wanting to be an engineer because of my experience with LEGOS® programming, and then later, involvement with my robotics team. Project Lead the Way (PLTW) was also a great influencer; it created an engaging, hands-on classroom environment and allowed us to develop in-demand knowledge and skills we need for a future in STEM. Conducting a study on early influencers on STEM careers, as early as junior high or elementary school, would help capture student interest in STEM.
- Conducting research on the impact social media can have on teen career choices would greatly help our understanding on youth development and career selection. We frequently communicate on our devices, and some of my classmates even aspire to have a career as a famous YouTube blogger. For example, there are students who enjoy watching livestreams of surgeries on the internet, and become inspired to be a doctor. Social media also provides exposure to other career options that may not be available in a classroom, so research in this area would be beneficial to potential STEM-career students.

Chairwoman COMSTOCK. Thank you. And I now recognize Dr. McCrary for five minutes to present his testimony.

TESTIMONY OF DR. VICTOR R. MCCRARY, VICE PRESIDENT, RESEARCH AND ECONOMIC DEVELOPMENT AND PROFESSOR OF CHEMISTRY, MORGAN STATE UNIVERSITY; MEMBER, NATIONAL SCIENCE BOARD AND CHAIR, TASK FORCE ON THE SKILLED TECHNICAL WORKFORCE

Dr. MCCRARY. Thank you, Chairwoman Comstock and Ranking Member Lipinski. On behalf of my colleagues on the National Science Board, I'm grateful for this opportunity.

The number of U.S. jobs requiring substantial STEM expertise has grown nearly 34 percent over the past decade. As of 2015, nearly one in seven workers with at least a four-year degree say their job requires a bachelor's level of STEM expertise. However, more than 16 million more jobs do not require a bachelor's degree yet require significant experience in at least one—and expertise in one technical field. Moreover, these jobs are growing in number.

At the same time, other countries are challenging our leadership in science and technology. Between 2000 and 2014, the number of Americans with four-year STEM degrees rose 53 percent. In China this number was 360 percent. Just last week, the National Science Board released a statement predicting that China would surpass the United States in R&D investment this year.

China's targeting up to 15 percent of their GDP at talent development, and China is not the only country that is chasing us. If we want to remain a world leader, we must leverage the hard work, creativity, and ingenuity of women and men of all ages, educational levels, and backgrounds. We need scientists searching for cures for genetic disorders, engineers securing our electrical grid, skilled technicians in our hospitals and labs, and farmers growing more with fewer resources. We can't do this by relying on a relatively small and distinct STEM workforce. Instead, government, business leaders, and educators must work together to build a STEM-capable U.S. workforce.

That workforce goes beyond traditional scientists and engineers to include the often-overlooked skilled technical workers who helped form the backbone of our economy. Skilled technical jobs are well-paying and are found across the United States. Businesses large and small need adaptable STEM-capable workers at every educational level and from all demographic groups in order to compete. But according to a survey conducted by the GAO, employers in 80 percent of local area said they had trouble filling jobs in skilled technical occupations.

Because we both see a need and an opportunity, the board has created in November of 2017 a Task Force on the Skilled Technical Workforce. I've submitted the task force charge along with my written testimony. We're exploring ways the NSB and NSF can help strengthen this segment of the workforce, including by identifying gaps in information and data, exploring ways to build and leverage partnerships, and examining evidence-informed approaches to re-

moving the barriers that far too many students and workers encounter.

Although it is still early in the work of the board's task force, I will use the remainder of my time to highlight several points that have already become clear to us. What we have here is a failure to, or, more specifically, to coordinate between businesses desperate for STEM-capable skilled U.S. workers and students and incumbent workers seeking well-paying, stable jobs. Too often, the students we produce or the training we provide to workers doesn't seem to align with what industry wants.

At the same time, industry hiring practice says can themselves be a barrier, for example, requiring a four-year degree for openings where a certification or two-year degree might be a better fit.

During a recent listening session at Baton Rouge Community College in Louisiana, board members sat at a table in which industry participants lamented their inability to find workers with specific skills and a community college student sitting right there at the table saying, "Hey, that's me."

We also see that there's a stigma associated with community colleges, technical schools, and vocational training in the minds of students, parents, employers, and yes, academics. We need to change that perception and fix our own blind spots and baggage to recognize how critical these workers are to the success of our nation's science and engineering enterprise.

To give you an example, last year the NSB visited LIGO in Louisiana. We heard of the LIGO scientist who won the Nobel Prize in physics for the discovery of gravitational waves, but what you might not know about LIGO is that it's an industrial facility, miles of carefully welded high vacuum pipeline and banks for air filters as tall as a house. It's skilled technical workers, HVAC experts, electricians, and other workers without a four-year degree who built that, keep it running, and they are fundamental to the scientific discoveries that are made. This is blue-collar STEM.

Next, we must better leverage our public investments. At NSF, programs like INCLUDES and Advanced Technological Education or ATE do this by facilitating partnerships between educational institutions and local businesses or between research-intensive universities like the University of Tennessee and local community colleges. We learn what works so others can take these practices to scale.

We have—all have a role to play in this. Technical schools, community colleges, trade labor organizations, chambers of commerce, industry, four-year colleges, research universities, and HBCUs like Morgan State University and other minority-serving institutions need it to create onramps into STEM for all segments of our population. We cannot compete without their inclusion and wholehearted participation.

I'm glad you're having this hearing, and I'm looking forward to learning from the rest of the witnesses.

Madam Chair, this concludes my testimony.

[The prepared statement of Dr. McCrary follows:]

Testimony of

Victor McCrary, PhD

Member

National Science Board

National Science Foundation

Before the

Subcommittee on Research and Technology

for the

Committee on Science, Space, and Technology

U.S. House of Representatives

February 15, 2018

"Innovations in STEM Mentoring, Training, and Apprenticeships"

Introduction: The Workforce of the Future

Ensuring the long-term strength of the Nation's scientific workforce has always been a core component of NSF's mission. Our workforce has been – and continues to be – the essence of American innovation, economic competitiveness, and national security. In 1950, Vannevar Bush wrote that "the responsibility for the creation of new scientific knowledge - and for most of its application - rests on that small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research." At that time this meant scientists and engineers engaged in research and development (R&D) in government, academic, or industry laboratories.

But science has progressed and our economy has evolved since NSF's founding. Bush's conception is now far too narrow. While the education and training of scientists and engineers who perform fundamental research—our Nation's "Discoverers"—remain central to NSF's mission, we now recognize that science, technology, engineering, and math (STEM) capabilities are important to the *entire* U.S. workforce **and** that the progress of science depends on more than just PhDs. As we look towards the next 70 years, the

NSB believes that for our Nation to continue to thrive and lead in a globally competitive knowledge- and technology-intensive economy we must do more than create a "STEM workforce"; Congress, the Administration, business leaders, educators, and other decision-makers must work together to create a **STEM-capable U.S. workforce**.

Scientific and technological advances have transformed the workplace, especially in traditionally middle-class, blue-collar jobs such as manufacturing. These and many other jobs now demand higher levels of STEM knowledge and skill. In 2015 about 14.3 million U.S. workers were employed in a STEM job. Yet in a survey of individuals with at least a four-year degree, including many working in sales, marketing, and management, an estimated 19.4 million reported that their job required at least a bachelor's degree level of STEM expertise. This does not include millions of workers who use technical competencies in their job, but who do not have a four-year degree. And the number of jobs requiring these skills is growing across all sectors of our economy.

Creating a STEM-capable U.S. workforce requires a much more expansive vision, one that includes students and workers at all education levels. Workers on the farm, the factory floor, and in the laboratory all need the ability to learn, adapt, install, debug, train, and maintain new processes or technologies. This vision includes women, traditionally underrepresented groups, military veterans, persons with disabilities, and blue-collar workers who were hard hit by transformations in the domestic and global economy.

Addressing the Growing National Need for a STEM-Capable Workforce

As both the policymaking body of NSF and as an independent advisor to Congress and the President on S&E issues, the National Science Board sees an opportunity in this conversation. Every two years, we produce and deliver *Science and Engineering Indicators*; the 2018 edition of the report was delivered last month. In that report, we provide the best available data on the S&E enterprise. The release of the report also provided us with an opportunity to update our understanding of the state of the nation's STEM workforce more broadly, using the latest data on national and international trends in STEM education and employment.

Though the main *Indicators* report is policy neutral, since the early 1990s the Board has published policy "companions" to *Indicators*. These companions draw on the *Indicators* data to highlight opportunities and challenges facing the S&E enterprise, provide policy insights or recommendations, and/or offer commentary on current or emerging trends in science and technology. Over the past several years, these briefs have been focused on various aspects of the Nation's STEM workforce, beginning with our *Revisiting the STEM Workforce* report, released in 2015.[1] I think our motivations are similar to those behind this hearing: we have watched the changes in our economy, in global competition, in education, and in the conduct of research and we want to ensure that our people, our businesses, and our Nation are prepared to adapt and thrive.

Revisiting the STEM Workforce contains three major findings that remain relevant in 2018:

(1) The STEM workforce it heterogeneous—it comprises individuals at all different education levels, working across the country in all sorts of jobs that require STEM know-how;

(2) We should think of transition from formal STEM education into a career and through retirement as a series of pathways with many branches rather than a linear pipeline. In today's knowledge- and technology- intensive economy, workers need to be lifelong learners, adapting and reinventing themselves over the course of a career; and

(3) While STEM capabilities are critical to unlocking many career pathways in today's economy, there are numerous roadblocks, particularly for women and groups underrepresented in STEM. We must overcome these barriers so that all people can thrive in a globally competitive, 21st century economy.

In 2016, the Board examined the STEM doctoral workforce. Over the past twenty years, its size has increased by more than 50%, far outpacing the growth in permanent academic positions. This situation generated conversations in academic and policy circles about a "surplus" of doctorates – yet the unemployment rate for these individuals is extremely low. The Board released a statement and interactive infographic on career paths for these individuals, showing that more than 50% of STEM doctorates are employed outside of the academic sector within ten years of graduation – and this trend has held over at least the last twenty years.[ii] Our brief shows that science and engineering doctorate holders have diverse career paths, bringing scientific thinking, analytical skills, and discipline-specific expertise to every sector of the U.S. economy. Advanced education provides individuals with access to many opportunities for meaningful and impactful careers, and benefits employers who rely on new and better ideas to innovate and compete.

Two weeks ago, the Board released a policy companion statement to *Indicators 2018* entitled, "Our Nation's Future Competitiveness Relies on Building a STEM-Capable U.S. Workforce."[iii] This statement updated and reinforced many of the themes from the 2015 workforce report. I have appended the full policy statement to my testimony, but would like to highlight a few key points here:

- The number of U.S. jobs requiring substantial STEM expertise has grown nearly 34% over the past decade. As of 2015, nearly one in seven workers with at least a four-year degree say that their job requires a "bachelor's level" of STEM expertise.[iv] Another 16 million skilled technical jobs – more than one in nine – do not require a bachelor's degree, yet require significant expertise in at least one technical field.[v]

- Other countries are challenging U.S. leadership in science and technology. Between 2000 and 2014, the number of Americans with a four-year degree in S&E grew by 53% (483,764 to 741,763); in China, this number was 360% (359,478 to 1,653,565).[vi]

Just last week the NSB released a statement predicting that China would surpass the United States in R&D investment later this year.[vii] While this is likely inevitable due to the size of their population and economy, China is investing specifically in education to fuel high-tech growth, targeting up to 15% of GDP at talent development. China is not alone – other countries are increasing investments in R&D and education to compete with the United States.[viii]

NSB's statement underscores that to succeed and compete in this new global landscape our Nation can no longer rely on a distinct and relatively small STEM workforce. We must work together to ensure *all* segments of our population have access to affordable, high-quality education and training opportunities beginning as early as kindergarten and lasting well beyond graduation. Today's workers need "on-ramps" and multiple pathways to develop the STEM expertise and other critical capabilities so they can adapt to constantly evolving workplace demands.[ix] The policy statement also highlights the need to focus on groups that are underutilized, yet essential to our future competitiveness: workers who use technical skills in their jobs but who do not have a four-year degree ("skilled technical workers"), people at all education levels who have been historically underrepresented in STEM, and military veterans returning from deployment.

Developing this STEM-capable U.S. workforce will provide our nation with an enduring competitive advantage – but building and sustaining it is no small feat. It will require cooperation and commitment from

local, state, and federal governments, education institutions at all levels, non-governmental organizations, and businesses large and small. Our statement has four recommendations:

(1) Governments at all levels should empower all segments of our population through investments in formal and informal education and workforce development throughout an individual's life-span. This includes redoubling our commitment to training the next generation of scientists and engineers through sustained and predictable Federal investments in graduate education and basic research.

(2) Businesses should invest in workplace learning programs – such as apprenticeships and internships–that utilize local talent. By leveraging partnerships between academic institutions and industry, businesses will be less likely to face a workforce "skills gap."

(3) Governments and businesses should expand their investments in community and technical colleges, which continue to provide individuals with on-ramps into skilled technical careers as well as opportunities for skill renewal and development for workers at all education levels throughout their careers.

(4) To accelerate progress on diversifying the STEM-capable U.S. workforce, the Nation should continue to invest in underrepresented segments of the population and leverage Minority Serving Institutions to this end.[x] The NSF INCLUDES ("Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science") and NIH ASCEND ("A Student-Centered Entrepreneurial Development") programs at Morgan State University are examples of such investments.[xi]

National Science Board Task Force on the Skilled Technical Workforce

A STEM-capable U.S. workforce includes not only traditional scientists and engineers performing research in university, government, or industry labs (a group which has received considerable attention from the NSB and other groups), but also the often-overlooked skilled technical workers who help form the backbone of our economy.

Skilled technical jobs are well-paying, and are found across the United States. They offer opportunities for incumbent workers who have been affected by automation and globalization, and they offer solid career pathways for traditional and nontraditional students who are not interested in, or who are unable to attend, a 4-year university. Businesses large and small across the United States—from Baltimore, Maryland to Livingston, Louisiana to Knoxville, Tennessee —need adaptable, STEM-capable workers at *every* education level and from *all* demographic groups in order to compete. Despite the need for these workers, business say they have difficulty filling these jobs. According to a survey conducted by the Government Accountability Office, employers in 80% of local areas said they had trouble filling jobs in occupations that depend on skilled technical workers.[xii]

One of the reasons for this "skills mismatch" is that that the job market is fast-moving and dynamic. Workers can no longer settle into a job and do the same tasks for years. They must be lifelong learners, adapting and evolving with changing technologies and markets. Education and training efforts aimed at developing the skilled technical workforce can help produce the kind of highly capable and adaptable workers who can fill jobs in critical areas such as healthcare, cybersecurity, research, and defense. At the same time, this education is an increasingly important on-ramp. Community colleges and technical schools, particularly for underrepresented minorities, have served as gateways to bachelors and PhDs in STEM fields.

These reasons led the NSB last November to formally create a Task Force on the Skilled Technical Workforce (STW). This Task Force is now exploring the opportunities and challenges facing students, workers, business, and educators involved with the skilled technical workforce, and identifying ways we can help. I have included the Charge to the Task Force with my written testimony.

So far the Task Force has conducted outreach to learn about the challenges facing students, businesses, educators, and policymakers involved in the skilled technical workforce. For example, last year the NSB visited the Laser Interferometer Gravitational-Wave Observatory (LIGO) in Louisiana. We have heard of the scientists who won the Nobel Prize in Physics for the discovery of gravitational waves at LIGO, but skilled technical workers—HVAC experts, electricians, and other workers without a four-year degree—helped build LIGO and keep it running. In addition to the LIGO visit, the NSB held "listening sessions" at Baton Rouge Community College and Xavier University to learn more about the opportunities and challenges facing the skilled technical workforce from a real-world, outside-of-the-Beltway perspective.

The objectives of the Task Force include:

- Identifying and examining data on the skilled technical workforce, including data on technical occupations, training, career pathways and outcome and identifying gaps in the currently available data.

- Considering strategies to leverage *Science and Engineering Indicators* as a possible outlet for existing and new data on the skilled technical workforce.

- Understanding the incentives and barriers to pursuing skilled technical occupations, including:
  - Secondary school preparation in math and science
  - Alignment of training programs with local and high-priority industry needs
  - Human resources recruitment/hiring practices
  - Cost of and access to education and mid-career retraining
  - Mentoring
  - Students, parents, educators, and other stakeholders' awareness and perception of these jobs

- Identifying strategies to enhance existing and foster new long-term partnerships among community colleges, 4-year colleges and universities, local business, labor and industries, national laboratories, nonprofits, and relevant state and Federal agencies; identify strategies for leveraging these partnerships.

- Exploring opportunities to further leverage current NSF investments in skilled technical workforce specifically, and STEM education and human capital development broadly, including making undergraduate and graduate education more relevant and responsive to changes in the composition and needs of a globally competitive domestic workforce.

- Identifying strategies for the Board and NSF to strengthen the skilled technical workforce that do not require additional Federal appropriations.

- Considering how technological change (e.g., automation) shapes the demands on the skilled technical workforce and the role that different education and training models play in enabling U.S. workers to adapt to these changes.

- Exploring how work on this dynamic and increasingly important segment of the STEM-capable workforce can inform current discussions around undergraduate and graduate education, including the growing importance of lifelong learning and discussions about the impact of skills and competencies assessments.

Current NSF Programs

From the perspective of NSF, helping to create a diverse, STEM-capable, globally competitive workforce is central to our mission. Continued taxpayer support demands that scientific and technological progress creates opportunities and benefits for **all** Americans. As the Board discussed in our recent policy statement, turning this vision into a reality requires the public, private, and nonprofit sectors to work in partnership to ensure that all Americans have access to high-quality, affordable education and training.

NSF remains at the forefront of creating the workforce of the future. Its investments span from kindergarten through graduate school and beyond, with a special emphasis on broadening the base of Americans who are STEM-capable.

The **Advanced Technological Education** (ATE) program, created in the early 1990s, is focused on two-year colleges and supports the education of technicians for the high-technology fields that drive our nation's economy. The program involves partnerships between academic institutions and industry to promote improvement in the education of science and engineering technicians at the undergraduate and secondary school levels. The ATE program particularly encourages proposals from Minority Serving Institutions, where the proportion of underrepresented students interested in advanced technology careers is growing. ATE supports curriculum development; professional development of college faculty and secondary school teachers; pathways to two-year colleges from secondary schools and from two-year to four-year institutions; and other activities. ATE invites research proposals that advance the knowledge base related to technician education and encourages partnerships with other entities that may impact technician education.

To date, ATE has awarded more than $950M total to 492 institutions, with over 65% of awards going to two-year degree granting institutions. Examples of the types of awards made by the ATE program include:

- The ATE Southeast Maritime and Transportation (SMART) Center focuses on increasing the number of well-qualified, skilled technicians in the maritime and transportation industry. The SMART Center leverages an existing registered apprenticeship program at Tidewater Community College (TCC) in preparing students to enter the industry. The Center has facilitated the creation of a new A.A.S. degree in Maritime Technologies at TCC, and has developed innovative training programs to meet employers' workforce development training requirements.

- The Kansas City Kansas Biomanufacturing Training Laboratory (KCKBTL) is working to develop the bioscience/biotechnology workforce for the Kansas City region. Project goals include: (1) defining and developing sequences of industry-validated courses that lead to a Certificate in Biomanufacturing or an Associate Degree in Bioscience and (2) providing professional development opportunities for high school science teachers and community college faculty members in topical areas that facilitate technician education in the life sciences. KCK

community college students will be placed into internships at local companies and in academic research laboratories at the University of Kansas Medical Center.

In short, ATE increases knowledge, catalyzes institutional change, and builds capacity.

The **Scholarships for STEM** (S-STEM) program, funded by H1-B petitioner fees, addresses the need for a high-quality STEM workforce and for the increased success of low-income academically talented students with demonstrated financial need who are pursuing associate, baccalaureate, or graduate degrees in STEM.

The program provides awards to Institutions of Higher Education to fund scholarships and to advance the adaptation, implementation, and study of effective evidence-based curricular and co-curricular activities that support recruitment, retention, transfer (if appropriate), student success, academic/career pathways, and graduation in STEM. The S-STEM program encourages collaborations among different types of partners: Partnerships among different types of institutions; collaborations of STEM faculty and institutional, educational, and social science researchers; and partnerships among institutions of higher education and local business and industry. The S-STEM program particularly encourages proposals from two-year institutions, MSIs, HBCUs, HSIs, tribal colleges, and urban public and rural institutions.

The program seeks: 1) to increase the number of low-income academically talented students with demonstrated financial need obtaining degrees in STEM and entering the workforce or graduate programs in STEM; 2) to improve the education of future scientists, engineers, and technicians, with a focus on academically talented low-income students; and 3) to generate knowledge to advance understanding of how factors or evidence-based curricular and co-curricular activities affect the success, retention, transfer, academic/career pathways, and graduation in STEM of low-income students.

The Cybersecurity Enhancement Act of 2014 authorized NSF, in coordination with OPM and the DHS, to offer a scholarship program to recruit and train the next generation of information technology professionals, industry control system security professionals and security managers. The resulting program, **CyberCorps – Scholarship for Service**, funds institutions of higher education to develop and enhance cybersecurity education programs and curricula; and to provide scholarships to undergraduate and graduate students in strong academic cybersecurity programs – an area of key strategic importance to U.S. national security. The students receiving scholarships must be U.S. citizens or lawful permanent residents and must be able to meet the eligibility and selection criteria for government employment. Students can be supported on these scholarships for up to three years, and in return, they agree to take government cybersecurity positions for the same duration as their scholarships. The program also requires a summer internship at a Federal agency. Government agencies eligible for job placement include Federal, state, local, and tribal governments.

The **Community College Innovation Challenge** (CCIC) is a prestigious, two-stage competition where community college teams use STEM to innovate solutions to real-world problems, compete for cash awards, and earn full travel support (students and faculty) to attend an Innovation Boot Camp in Washington, D.C. A highlight of the Boot Camp is the reception for the finalists here on Capitol Hill, at which the teams exhibit their challenge projects. The challenge program strengthens and develops STEM thinking by applying it to solving real-world problems; creates deeper engagement and interactions between students and faculty mentors, and with industry; and promotes the larger ecosystem that carries invention from idea to beneficial innovation.

As part of the Board's fact-finding on the Skilled Technical Workforce, last year we were fortunate to meet with a young man who shared with us his circuitous path into STEM. Talented but rebellious as a teenager, by his late 20s, he found himself stuck in a job that barely paid the bills for his family, but with

a yearning to use his brain to work on more challenging problems. Thanks to support through NSF's community college programs, and his participation in the CCIC, this young man won an internship at NASA's Jet Propulsion Laboratory and is now well on his way to fulfilling his dream and contributing to America's science and engineering story. And he is "paying it forward" – he founded an organization in his state that creates opportunities for community college students to build leadership skills, conduct undergraduate research, and do community outreach to local public school students who are interested in STEM careers and academic paths. There are countless other such stories that illustrate the success of NSF's programs in attracting students from diverse backgrounds into STEM education and careers – and which illustrate the fact that individuals do not have to be born to scientists or technicians to become a successful scientist or technician.

NSF contributes to the education and training of the next generation of STEM-capable workers in other critical ways. As Congress emphasized in the *American Innovation and Competitiveness Act*, hands-on research opportunities for undergraduates, especially in the early years of their university education, help to increase student interest and retention in STEM disciplines. NSF supports such experiences in two primary ways. The **Research Experiences for Undergraduates** (REU) program supports active research participation by undergraduate students in the areas of research funded by NSF. **Classroom-based Undergraduate Research Experiences** (CUREs) replace introductory STEM courses or textbook laboratory exercises with discovery-based research problems, potentially delivering research experiences to many more students – including non-STEM majors. Through our Education and Human Resources (EHR) Directorate, NSF is also actively working to develop new strategies to encourage more research experiences for students at two-year institutions.

A STEM-capable U.S. workforce requires workers at every education level, including workers engaged in research and development activities. NSF is a leader in educating the next generation of PhD scientists and engineers through grants awarded via our research directorates and through our signature **Graduate Research Fellowship Program**, which directly supports graduate students in all STEM fields. NSF also has a new internship initiative, the **Graduate Research Internship Program**, which expands opportunities for NSF Graduate Fellows to enhance their professional development by engaging in mission related research experiences with partner agencies across the federal government.

Individuals with advanced degrees in STEM not only generate new knowledge through R&D activities that fuel innovation, but they also add value throughout our economy in STEM and non-STEM jobs alike. The **NSF Research Traineeship** (NRT) program encourages the development and implementation of potentially transformative models for interdisciplinary STEM graduate training that enable diverse cohorts of graduate students develop the skills, knowledge, and competencies to pursue a range of STEM careers, especially in areas of national need, such as cybersecurity and data science, brain research, and the food-energy-water nexus. NRT emphasizes institutional capacity building and encourages partnerships with the private sector, non-governmental organizations, government agencies, national labs, and other relevant groups.

Deeply embedded in the vision of a STEM-capable U.S. workforce is the imperative that all Americans be afforded the opportunity to participate in and reap the benefits of our Nation's great scientific endeavor. NSF supports this goal through its numerous investments aimed at tapping into populations historically underrepresented in STEM. **NSF INCLUDES** is a key national initiative designed to ensure that all Americans have access to educational and career opportunities enabled by STEM.

In addition, NSF's **HBCU-Undergraduate Program** (HBCU-UP) provides awards to strengthen STEM undergraduate education and research at HBCUs. A new component of this program, **HBCU Excellence in Research**, supports projects that enable STEM and STEM education faculty to further develop research capacity at HBCUs and to conduct research. HBCU-UP also funds **Broadening Participation**

Research Centers (BPRC). BPRCs are expected to represent the collective intelligence of HBCU STEM higher education, and serve as national hubs for the rigorous study and broad dissemination of the critical pedagogies and culturally sensitive interventions that contribute to the success of HBCUs in educating African American STEM undergraduates. Centers are expected to conduct research on STEM education and broadening participation in STEM; perform outreach to HBCUs to build capacity for conducting this type of research; and work to disseminate promising broadening participation research in order to enhance STEM education and research outcomes for African American undergraduates across the country.

NSF administers the **Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring** (PAESMEM), a Presidential award established by the White House in 1995. PAESMEM is the highest honor bestowed upon mentors who work to expand STEM talent. Individuals and organizations in all public and private sectors are eligible including industry, academia, K-12, military and government, non-profit organizations, and foundations. PAESMEM awardees serve as leaders in the national effort to develop fully the Nation's human resources in STEM.

Conclusion

Although it is still early in the work of the Board's STW Task Force, I will conclude by highlighting several key points that have already become clear to us.

As the Captain said in the movie *Cool Hand Luke*: "what we have is a failure to communicate" – or more specifically, coordinate. Businesses desperately need STEM-capable, skilled workers, while students and incumbent workers desperately want well-paying, stable jobs. But too often the students we produce or the training we provide to workers doesn't seem to align with what industry wants. At the same time, industry hiring practices can themselves be a barrier – for example, requiring a 4-year degree for openings where a certification or 2-year degree might be a better fit. In Louisiana, Board members literally sat a table in which industry participants lamented their inability to find workers with specific skills – and a community college student said "that's me!"

Following that point, all too often, this is the message that parents and educators and employers alike are sending: it's 4-year college or bust. There is a stigma associated with community colleges, technical schools, and vocational training in the minds of students, parents, businesses – and yes, academics. We educators need to work towards changes that perception. This is an opportunity the National Science Board is trying to seize.

Next, we must identify multipliers. We must make our public investments do more for us. At NSF, we do this by encouraging partnerships between education institutions and local businesses, or between research intensive universities and local community colleges. We learn what works so others can take these practices to scale.

Most importantly, we need to change the conversation. STEM is not just for elite institutions or for researchers with advanced degrees – it's for all Americans. STEM knowledge and skills are vital for our businesses to compete in today's world, and for bringing better jobs and greater prosperity to every region of this country. Strengthening the skilled technical workforce is an essential way to meet this imperative.

We all have a role to play in this. Technical schools, community colleges, like Howard County Community College, trade and labor organizations, chambers of commerce, industry, and 4-year colleges, research universities and HBCUs like Morgan State are needed to build and expand the STEM workforce at all educational levels. Government and academia need to step up to help change the narrative around the Skilled Technical Workforce.

A STEM-capable U.S. workforce is vital to the well-being of our society and to the economic competitiveness of our Nation. We should care about this workforce because the importance and pervasiveness of science and technology in our economy is growing. We should care because we live in a global economy where knowledge is king, and in this new world we should do all we can to make sure none of our citizens are left behind.

Enclosures:

- Charge to the National Science Board Task Force on the Skilled Technical Workforce
- National Science Board Policy Companion Statement to *Science and Engineering Indicators 2018*: "Our Nation's Future Competitiveness Relies on Building a STEM-Capable U.S. Workforce"

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[i] https://www.nsf.gov/nsb/publications/2015/nsb201510.pdf
[ii] https://www.nsf.gov/nsb/sei/infographic2/
[iii] https://www.nsf.gov/nsb/sei/companion-brief/NSB-2018-7.pdf
[iv] Survey data collected using the National Survey of College Graduates (NSCG) showed that 19,366,000 respondents stated that their job requires S&E technical expertise at the bachelor's level. See National Science Board, *Science and Engineering Indicators 2018* (Alexandria, VA: National Science Board, 2018), Table 3-3. For more information on the NSCG, see https://nsf.gov/statistics/srvygrads/#sd.
[v] Jonathan Rothwell, "Defining Skilled Technical Work," (Washington, DC: National Academies, 2015). Retrieved from: http://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_167744.pdf.
[vi] *Indicators 2018*, Appendix Table 2-35.
[vii] https://www.nsf.gov/nsb/news/news_summ.jsp?cntn_id=244465&org=NSB&from=news
[viii] For example, between 2000 and 2010 South Korea experienced 11% average annual growth in R&D spending and 7.3% growth rate between 2010-15 (or 8.6% and 5.5%, respectively, when adjusted for inflation). South Korea now accounts for 4% of global R&D spending. *Indicators 2018*, Appendix Table 4-12.
[ix] Other critical capabilities include communication skills, the ability to work in teams, and problem solving and critical thinking skills.
[x] Minority Serving Institutions include Historically Black Colleges & Universities (HBCUs), Hispanic Serving Institutions (HSIs), and Tribal Colleges and Universities (TCUs).
[xi] For more information on NSF INCLUDES, see https://www.nsf.gov/news/special_reports/nsfincludes/index.jsp. The Morgan State University ASCEND program is part of NIH's BUILD (Building Infrastructure Leading to Diversity) Initiative. For more information on BUILD, see https://www.nigms.nih.gov/training/dpc/pages/build.aspx.
[xii] For example, employers had trouble filling jobs in the following occupational categories: Installation, Maintenance, and Repair; Construction and Extraction; Healthcare Practitioners and Technical Occupations; Production; and Computer and Mathematical Occupations. In the report, the term "local areas" refers to the areas overseen by both local and statewide Workforce Investment Boards (WIBs). For more information, see https://www.gao.gov/assets/660/659322.pdf.

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CHARGE TO THE TASK FORCE ON THE SKILLED TECHNICAL WORKFORCE

Action Recommended

The National Science Board (NSB; Board) Task Force on the Skilled Technical Workforce is established and charged to identify the opportunities and challenges facing students, incumbent workers, businesses, educators, and others involved with the skilled technical workforce (STW) and recommend to the NSB strategies, including possible policies, for strengthening the STW.

In fulfilling this charge, the Task Force is expected to work closely with NSF and relevant stakeholders within and outside the government.

Statutory Basis

"The Board shall render to the President and the Congress reports on specific, individual policy matters within the authority of the Foundation (or otherwise as requested by the Congress or the President) related to science and engineering and education in science and engineering, as the Board, the President, or the Congress determines the need for such report." 42 U.S.C. § 1863(j)(2)

Linkage to NSF Mission

NSF is directed to support "...programs to strengthen scientific research potential and science education programs at all levels in the mathematical, physical, medical, biological, social, and other sciences...and programs to strengthen engineering research potential and engineering education programs at all levels in the various fields of engineering..." [42 U.S.C. § 1862(a)(1)]. NSF is also directed to support scientific and technical education by strengthening and expanding the scientific and technical education and training capabilities of associate-degree-granting colleges. [42 U.S.C. § 1862(h)]

Rationale

The National Science Foundation (NSF) has a broad mission with respect to creating a science, technology, engineering, and math (STEM)-capable U.S. workforce. In its 2015 report, *Revisiting the STEM Workforce*, the NSB called for creating a STEM-capable U.S. workforce comprising individuals from all demographic groups, at all education levels, and in all geographical locales who need STEM capabilities to succeed in a knowledge-based, globally competitive economy.

The pervasiveness of science and technology (S&T) in the economy has changed the nature of work for individuals at all education levels, including those without a 4-year degree. There are over 16 million skilled technical jobs for workers with an associate degree, or similar qualification rather than a bachelor's degree. The individuals who use STEM knowledge and skills in their jobs but who do not have a 4-year degree make up the "skilled technical workforce."

Skilled technical workers are important to U.S. economic competitiveness. Businesses cite the availability of highly skilled workers as critical to their ability to compete globally, yet regularly express difficulty in finding workers to fill these jobs. The STW also plays an important role in advancing our national security. Industries that are critical to our national security and defense—including aerospace, advanced manufacturing, information technology, healthcare, and cybersecurity—rely on access to these workers. The STW is also important to scientific progress. Industry representatives estimate that they need between 7–20 skilled technicians for every scientist or engineer with an advanced degree.

There are several ways that individuals gain these skills, including military training, apprenticeships, associate degrees and certificate programs. Because of the flexibility, accessibility, and relative affordability of the programs they offer, community and technical colleges serve as a key entry point into the STW for students from all backgrounds. They provide these students with linkages to local industry, but also empower them to pursue further education and follow multiple pathways into STEM careers. According to National Center for Science and Engineering Statistics (NCSES) data, 47% of all recent S&E graduates had done some coursework in a community college.

Community and technical colleges serve a diverse student body. More than half (56%) of all community college students are female. The majority of Native American (56%) and Hispanic (52%) undergraduates choose to pursue a college education at community colleges. African Americans (43%) and Asian Pacific Islanders (40%) undergraduate students also enroll in community college programs at high rates.[1]

Objectives

The Task Force on the Skilled Technical Workforce will assess how the Board and Foundation might strengthen the STW in the United States. The Task Force may:

- Identify and examine data on the STW, including data on technical occupations, training, career pathways and outcomes; identify gaps in the currently available data.
- Consider strategies to leverage *Science and Engineering Indicators* (*Indicators*) and *Indicators*-related resources as a possible outlet for existing and new data on the STW.
- Understand the incentives and barriers to pursuing skilled technical occupations, including:
  - Secondary school preparation in math and science
  - Alignment of training programs with local and high-priority industry needs
  - Human resources (HR) recruitment/hiring practices
  - Cost of and access to education and mid-career retraining
  - Mentoring
  - Students, parents, educators, and other stakeholders' awareness and perception of these jobs

[1] See Fast Facts published by the American Association of Community Colleges, http://www.aacc nche.edu/AboutCC/Pages/fastfactsfactsheet.aspx.

- Identify strategies to enhance existing and foster new long-term partnerships among community colleges, 4-year colleges and universities, local business, labor and industries, national laboratories, nonprofits, and relevant state and Federal agencies; identify strategies for leveraging these partnerships.
- Explore opportunities to further leverage current NSF investments in STW specifically, and STEM education and human capital development broadly, including making undergraduate and graduate education more relevant and responsive to changes in the composition and needs of a globally competitive domestic workforce.
- Identify strategies for the Board (full Board and standing committees) and NSF to strengthen the skilled technical workforce that do not require additional Federal appropriations.
- Consider how technological change (e.g., automation) shapes the demands on the STW and the role that different education and training models play in enabling U.S. workers to adapt to these changes.
- Explore how work on this dynamic and increasingly important segment of the STEM-capable workforce can inform current discussions around undergraduate and graduate education, including the growing importance of lifelong learning and discussions about the impact of skills and competencies assessments.

WORKPLAN

The Task Force will host two to three listening sessions in areas of the country with diverse stakeholders (e.g., industries, technical occupations, and two-year educational systems). The first listening session will take place at Baton Rouge Community College on October 26, 2017. The Task Force will also host a stakeholder symposium in the first half of 2018. The purpose of the symposium will be to convene experts and representatives from various employment sectors to better understand the opportunities and challenges for those in or involved with the STW.

Potential outcomes for the Task Force's activities include the following:

- A NSB report that captures the major findings of the Task Force that will enable better policy decisions relating to the STW.
- Recommendations for additions/changes to *Science and Engineering Indicators* and *Indicators*-related resources to improve our ability to understand the STW, including recommendations regarding data collection efforts.
- Materials (e.g., one-pagers, infographics, talking points) for NSB members to engage with key stakeholders (e.g., Congress, Administration) on the skilled technical workforce.

Duration of the Task Force

The Task Force is expected to complete its major activities within 18 months of approval of this Charge. The Task Force is also expected to provide the NSB with an interim report of its activities, including any modifications to its objectives and a list of expected deliverables, following the Stakeholder Symposium.

National Science Board
Science and Engineering Indicators 2018

OUR NATION'S FUTURE COMPETITIVENESS RELIES ON BUILDING A STEM-CAPABLE U.S. WORKFORCE

A Policy Companion Statement to *Science and Engineering Indicators 2018*

The number of jobs in the United States (U.S.) requiring substantial science, technology, engineering, and mathematics (STEM) expertise has grown nearly 34% over the past decade. As of 2015, nearly one in seven workers with at least a four-year degree say that their job requires a "bachelor's level" of STEM expertise.[1] Another 16 million skilled technical jobs–more than one in nine–do not require a bachelor's degree, yet require significant expertise in at least one technical field.[2]

At the same time, other countries are challenging U.S. leadership in science and technology. Between 2000 and 2014, the number of Americans with a four-year degree in S&E grew by 53% (483,764 to 741,763); in China, this number was 360% (359,478 to 1,653,565).[3] China's investments in higher education and research and development (R&D) have fueled the rapid growth of its high-technology industries.[4] Their high-tech manufacturing output now ranks number two in the world, trailing only the U.S.[5] China is not alone–other countries are increasing investments in R&D and education to compete with the U.S. (Figure 1).[6]

We Must Take Advantage of our Nation's Greatest Asset–Our People

As science and technology transform our economy and global competition grows, our Nation must focus on its greatest asset–our people. The U.S. can no longer rely on a distinct and relatively small "STEM workforce."[7] Instead, we need a STEM-capable U.S. workforce that leverages the hard work, creativity, and ingenuity of women and men of all ages, all education levels, and all backgrounds.[8] We need scientists searching for cures for genetic disorders, engineers revolutionizing and securing our electrical grid, skilled technicians improving the operations of our research facilities and hospitals, and farmers producing healthier crops utilizing new technologies that at the same time consume fewer resources.

A STEM-capable workforce provides the U.S. with an enduring competitive advantage. Building and sustaining it will require cooperation and commitment from local, state, and federal governments, education institutions at all levels, non-governmental organizations, and businesses large and small. As a nation, we must work together to ensure *all* segments of our population have access to affordable, high-quality education and training opportunities beginning as early as kindergarten and lasting well beyond graduation. Today's workers need "on-ramps" to develop the STEM expertise and other critical capabilities so they can adapt and thrive.[9] Most of all, we must ensure that no Americans are left behind. All our people must be armed with the skills and knowledge to meet the future head on.

Among the groups that are underutilized, yet essential to our future competitiveness, are workers who use technical skills in their jobs but who do not have a four-year degree ("skilled technical workers") and people at all education levels who have been historically underrepresented in STEM. Growing the skilled technical workforce and reducing barriers to participation in STEM will increase individual economic opportunity and support our Nation's leadership in science and technology.

The Skilled Technical Workforce

The most important and defining feature of a STEM-capable U.S. workforce is that it leverages the talents of people at all education levels and in all sectors. It not only includes traditional scientists and engineers performing research in university, government, or industry labs, but also "skilled technical workers" who can install, repair, debug, and build, but who do not have four-year degrees.[10]

Though sometimes overlooked, the skilled technical workforce is large and diverse. These workers can be found in cities, towns, and rural areas throughout the U.S. Estimates of the size of the skilled technical workforce vary from just over 6.1 million to over 16.1 million. The size of this workforce is growing. The composition of this segment of the U.S. workforce closely mirrors U.S. population demographics. In 2015, about 13% of skilled technical workers in STEM jobs were black, 10% were Hispanic, 4% were Asian, and about 11% were foreign born.[11]

These workers are a crucial component of almost every sector of the U.S. economy, ranging from "blue collar" occupations, such as installation, maintenance, and repair, to healthcare and computer occupations. Skilled technical workers are also critical to the operation of our Nation's research infrastructure. The Nobel-Prize winning discovery of gravitational waves at NSF's Laser Interferometer Gravitational-Wave Observatory (LIGO) would not have been possible without the invaluable expertise of the people who assemble and maintain the facility's large and complex heating, ventilation, vacuum, air conditioning, and electronic systems.

Skilled technical jobs are in high demand and pay well. In 2015, the median earnings of skilled technical workers in S&E ($60,000) or S&E-related ($45,000) occupations were significantly higher than the median earnings in other occupations ($29,000).[12] These occupations are expected to have the fastest growth over the next decade.[13] Despite this, employers in 80% of local areas said they had trouble filling jobs in occupations that depend on skilled technical workers, according to a survey conducted by the Government Accountability Office.[14] Coordinated policies and investments aimed at building and strengthening on-ramps into skilled technical careers will help address labor market demands, increase the number of STEM-capable workers, and provide workers with the knowledge and skills needed to adapt to an evolving workplace.

Groups Underrepresented in STEM

The National Science Board believes that America's demographic diversity is a distinct competitive advantage. Research shows that diverse companies have better strategies, are more innovative, and win economically.[15] Numerous entities, including the National Science Foundation (NSF), have undertaken a myriad of initiatives spanning decades aimed at leveraging the talents of all segments of our population, especially groups historically underrepresented in STEM. Yet, in spite of some progress, crippling disparities in STEM education remain (Figure 2).

Although women have earned about half of all science and engineering (S&E) bachelor's degrees since the late 1990s, their levels of participation vary widely across S&E fields (Figure 3). The proportion of bachelor's degrees awarded to women in high demand fields such as computer sciences (18%) and engineering (20%) remain low.[16] Overall, while women occupy half of all jobs in the U.S. workforce, they constitute slightly less than 28% of workers in S&E occupations.[17]

The talents of minority groups in the U.S. are perhaps our greatest untapped resource. Hispanics, blacks, and American Indians or Alaska Natives together make up 27% of the U.S. population age 21 and older, but only 15% of those who hold their highest degree in S&E and 11% of workers in S&E occupations.[18] The proportion of S&E bachelor's degrees awarded to blacks remained flat at 9% between 2000 and 2015 (32,993 to 53,649).[19] These gaps are even more pronounced at the doctoral level where blacks earned 4% of all S&E doctoral degrees awarded in 2015.[20] In 2015, blacks accounted for 12% of the U.S. population 21 or older but only 5% of S&E job holders.[21] The negative consequences of these gaps will only grow: according to a recent report, nearly 25% of black workers are concentrated in 20 occupations that are at high risk of automation, such as cashiers, cooks, security guards, drivers, and administrative assistants.[22]

The share of bachelor's degrees in S&E awarded to Hispanics increased from 7% (27,980) to 12% (79,203) between 2000 and 2015.[23] Despite these gains, Hispanics accounted for 6% of employment in S&E occupations in 2015, well below their share of the U.S. population age 21 and older (15%).[24] The proportion of bachelor's degrees earned by Hispanics in high-demand fields such as computer science (10%) and engineering (10%) remain low.[25] The changing demographics of the U.S. population will amplify the consequences of these gaps since increased enrollment in higher education is expected to come mainly from minority groups, particularly Hispanics.

Military veterans returning from deployment are another group whose skills are often underutilized. Many possess technical training and have significant experience with advanced technologies and systems.[26] Several initiatives focused on academic advising, internships, networking services and peer support are underway to alleviate the roadblocks that veterans encounter as they enter the civilian workforce.[27] To help inform these efforts, the National Science Foundation's National Center for Science and Engineering Statistics is beginning to collect data that will reveal the relationship between education and career pathways for veterans with four-year degrees.

Attracting and Retaining the Best Internationally Mobile Students

Up to this point, our Nation has compensated for the failure to take full advantage of all segments of the population by attracting the best students from around the globe. This is especially true at the graduate degree level, where foreign-born[28] students earn over one-third of all U.S. STEM doctorates, including nearly half of the degrees in engineering and computer science.[29] While the U.S. remains the top destination for internationally mobile students, its share of these students declined from 25% in 2000 to 19% in 2015 as other countries increasingly compete for them.[30]

Our Nation's ability to attract students from around the world is important, but our competitive advantage in this area is fully realized when these individuals stay to work in the United States post-graduation. The overall "stay rates" for foreign-born non-citizens who received a Ph.D. from U.S. institutions have generally trended upwards since the turn of the century, reaching 70% for both the 5-year and 10-year stay rates in 2015.[31] However, the percentage of new STEM doctorates from China and India—the two top countries of origin—with *definite plans to stay* in the U.S. has declined over the past decade (from 59% to 49% for China and 62% to 51% for India).[32] As other nations build their innovation capacity through investments in R&D and higher education, we must actively find ways to attract and retain foreign talent and fully capitalize on our own citizens.

Building the U.S. Workforce of the Future Requires Our Collective Effort

STEM knowledge and skills will continue to play a critical role in fostering individual opportunity and national competitiveness. Strengthening a diverse STEM-capable U.S. workforce that leverages the talents of all segments of our population has never been more important. Considering the increasing demands placed on students, workers, businesses, and government budgets, institutions must partner to build the U.S. workforce of the future. These joint efforts are necessary in order to prosper in an increasingly globally competitive knowledge- and technology- intensive world.

- Governments at all levels should empower all segments of our population through investments in formal and informal education and workforce development throughout an individual's life-span. This includes redoubling our commitment to training the next generation of scientists and engineers through sustained and predictable Federal investments in graduate education and basic research.

NSF must continue to do its part.

In recognition of the importance of catalyzing cross-sector partnerships, NSF launched the *Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science* (INCLUDES) program in 2016. INCLUDES aims to expand the composition of the STEM-capable workforce by developing scalable ways to grow the STEM-capable workforce by building new and strengthening existing partnerships.

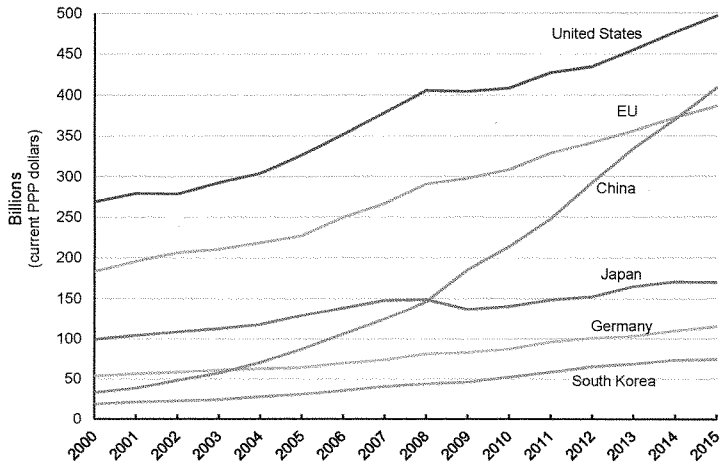
- Businesses should invest in workplace learning programs–such as apprenticeships and internships–that utilize local talent. By leveraging partnerships between academic institutions and industry, such as those catalyzed by NSF's Advanced Technological Education Program (ATE), businesses will be less likely to face a workforce "skills gap."

- Governments and businesses should expand their investments in community and technical colleges, which continue to provide individuals with on-ramps into skilled technical careers as well as opportunities for skill renewal and development for workers at all education levels throughout their careers.

- To accelerate progress on diversifying the STEM-capable U.S. workforce, the Nation should continue to invest in underrepresented segments of the population and leverage Minority Serving Institutions to this end.[33]

Collectively, we must proceed with urgency and purpose to ensure that this Nation and all our people are ready to meet the challenges and opportunities of the future.

FIGURE 1: Gross domestic expenditures on R&D, by the U.S., China, and selected other countries: 2000–2015

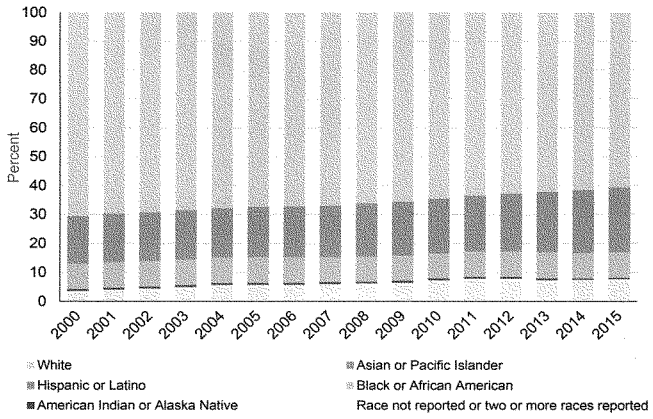


EU = European Union; PPP = purchasing power parity

Notes: Data are selected R&D-performing countries and the EU. Data are not available for all countries for all years. Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D.

Sources: National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2017/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, data.uis.unesco.org, accessed 13 October 2017. Adapted from Figure 4-6, *Science and Engineering Indicators 2018*. (Also see Appendix Table 4–12.)

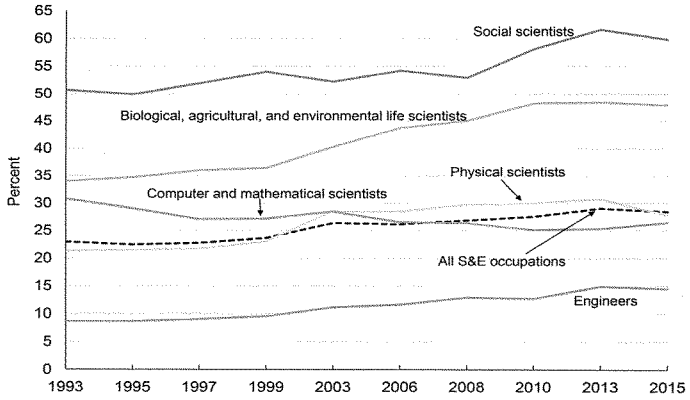
FIGURE 2: Share of S&E bachelor's degrees among U.S. citizens and permanent residents: 2000-15
By race and ethnicity



Notes: Hispanic may be any race. American Indian or Alaska Native, Asian or Pacific Islander, black or African American, and white refer to individuals who are not of Hispanic origin.

Sources: National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), Completions Survey; National Science Foundation, National Center for Science and Engineering Statistics, WebCASPAR database, https://ncsesdata.nsf.gov/webcaspar/. Adapted from Figure 2-12, *Science and Engineering Indicators 2018.*

FIGURE 3: Women in S&E occupations: 1993–2015



Notes: National estimates were not available from the Scientists and Engineers Statistical Data System (SESTAT) in 2001.

Sources: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (1993–2013), https://www.nsf.gov/statistics/sestat/, and the National Survey of College Graduates (NSCG) (2015), https://www.nsf.gov/statistics/srvygrads/. Adapted from Figure 3-27, *Science and Engineering Indicators 2018.*

ENDNOTES

1 Survey data collected using the National Survey of College Graduates (NSCG) showed that 19,366,000 respondents stated that their job requires S&E technical expertise at the bachelor's level. See National Science Board, *Science and Engineering Indicators 2018* (Alexandria, VA: National Science Board, 2018), Table 3-3. For more information on the NSCG, see https://nsf.gov/statistics/srvygrads/#sd.

2 Jonathan Rothwell, "Defining Skilled Technical Work," (Washington, DC: National Academies, 2015). Retrieved from: http://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_167744.pdf.

3 *Indicators 2018*, Appendix Table 2-35.

4 The pace of China's increase in R&D performance (measured as expenditures) has been exceptionally high over numerous years, averaging 20.5% annually over 2000–10 and 13.9% for 2010–15 (or 18.0% and 12.0%, respectively, when adjusted for inflation). This represents an increase in gross expenditures on R&D and expenditures for R&D (GERD) from $40.4 billion in 2000 to $371.6 billion in 2015 (2009 constant PPP $ billions). *Indicators 2018*, Appendix Table 4-12.

5 *Indicators 2018*, 6-5.

6 For example, between 2000 and 2010 South Korea experienced 11% average annual growth in R&D spending and 7.3% growth rate between 2010-15 (or 8.6% and 5.5%, respectively, when adjusted for inflation). South Korea now accounts for 4% of global R&D spending. *Indicators 2018*, Appendix Table 4-12.

7 According to the Bureau of Labor Statistics (BLS), the majority of net job openings (57%) and largest growth rate (15%) in NSF-identified S&E occupations for the period 2014-2024 are projected to be in computer and mathematical science occupations. Engineering occupations, the second largest subcategory of S&E occupations, are expected to generate about one-fourth (27%) of all job openings in S&E occupations during the same period. It is important to note that projected changes in the labor force and employment do not necessarily imply a labor shortage or surplus. For more on BLS occupational projections, see https://www.bls.gov/emp/.

8 Paul M. Romer, "Human capital and growth: Theory and evidence," *Carnegie-Rochester Conference Series on Public Policy* 32, no. 1 (Spring 1990): 251-286; Eric A. Hanushek and Ludger Woessmann, "Do better schools lead to more growth? Cognitive skills, economic outcomes, and causation," *Journal of Economic Growth* 17, no. 4 (December 2012): 267-321.

9 Other critical capabilities include communication skills, the ability to work in teams, and problem solving and critical thinking skills.

10 In November 2017, the National Science Board established a Task Force on the Skilled Technical Workforce. For more information, see https://nsf.gov/nsb/committees/stwcmte.jsp.

11 In 2015, the corresponding shares among workers in STEM occupations with four-year degrees were 7% black, 6% Hispanic, 17% Asian, and 24% foreign born. *Indicators 2018*, 3-84.

12 *Indicators 2018*, 3-84.

13 For more information on employment projections published by the Bureau of Labor Statistics, see https://www.bls.gov/emp/ep_table_103.htm.

14 For example, employers had trouble filling jobs in the following occupational categories: Installation, Maintenance, and Repair; Construction and Extraction; Healthcare Practitioners and Technical Occupations; Production; and Computer and Mathematical Occupations. In the report, the term "local areas" refers to the areas overseen by both local and statewide Workforce Investment Boards (WIBs). For more information, see https://www.gao.gov/assets/660/659322.pdf.

15 See Robin J. Ely and David A. Thomas, "Cultural Diversity at Work: The Effects of Diversity Perspectives on Work Group Processes and Outcomes," *Administrative Science Quarterly* 46, 2 (June 2001): 229-273; David A. Thomas, "Diversity as Strategy," *Harvard Business Review* 89, no. 9 (September 2004): 98; Sylvia Ann Hewlett, Melinda Marshall, and Laura Sherbin, "How diversity can drive innovation," *Harvard Business Review* 91, no. 12 (December 2013): 30; Vivian Hunt, Dennis Layton and Sara Prince, *Diversity Matters* (McKinsey & Company, 2015). Retrieved from: https://www.mckinsey.com/business-functions/organization/our-insights/why-diversity-matters.

16 National Science Foundation, *Women, Minorities, and Persons with Disabilities in Science and Engineering* (Arlington, VA: National Center for Science and Engineering Statistics, 2017). Retrieved from: https://www.nsf.gov/statistics/2017/nsf17310/digest/about-this-report/.

17 *Indicators 2018*, 3-8.

18 *Indicators 2018*, 3-8.

19 *Indicators 2018*, Appendix Table 2-22.

20 *Indicators 2018*, Appendix Table 2-32.

21 *Indicators 2018*, Table 3-19.

22 Spencer Overton, "The Impact of Automation on Black Jobs," (Washington, DC: Joint Center for Political and Economic Studies, 2017). Retrieved from: http://jointcenter.org/sites/default/files/The%20Impact%20of%20Automation%20on%20Black%20Jobs.pdf. For the impact on innovation, see David Leonhardt, "Lost Einsteins: The Innovations We're Missing," *New York Times*, 3 December 2017. Retrieved from: https://www.nytimes.com/2017/12/03/opinion/lost-einsteins-innovation-inequality.html.

23 These rates are for U.S. citizens and permanent residents as a proportion of all earned bachelor's degrees awarded in S&E. *Indicators 2018*, Appendix Table 2-22.

24 *Indicators 2018*, 3-116.

25 *Indicators 2018*, Appendix Table 2-22.

26 Numerous programs designed to maximize employment opportunities for veterans have focused on helping veterans transition from the military to the civilian workforce. These programs range from changes to the GI Bill, the Transition Assistance Program, and Vocational Rehabilitation and Employment services. For an overview of the range of transition programs for veterans as well as key challenges, see National Academies, "Building America's Skilled Technical Workforce," (Washington, DC: National Academies Press, 2017), 115-121.

27 See H.R.3218 - Harry W. Colmery Veterans Educational Assistance Act of 2017, https://www.congress.gov/bill/115th-congress/house-bill/3218/text?q=%7B%22search%22%3A%5B%22hr+3218%22%5D%7D&r=1.

28 *Foreign-born* is a broad category, ranging from long-term U.S. residents with strong roots in the United States to recent immigrants who compete in global job markets and whose main social, educational, and economic ties are in their countries of origin.

29 *Indicators 2018*, Appendix Table 2-29.

30 According to data from UNESCO/UIS, the number of internationally mobile students who pursued a higher education degree more than doubled between 2000 and 2014, to 4.3 million. For discussion of internationally mobile students see *Indicators 2018*, 2-96.

31 Long-term stay rates indicate the degree to which foreign-born non-citizens recipients of U.S. S&E doctorates enter and remain in the U.S. workforce to pursue their careers. The 10-year and 5-year stay rates in 2015 refer to the proportion of 2005 and 2010 graduating cohorts, respectively, who reported living in the United States in 2015. See *Indicators 2018*, Table 3-27.

32 *Indicators 2018*, Appendix Table 3-21.

33 Minority Serving Institutions include Historically Black Colleges & Universities (HBCUs), Hispanic Serving Institutions (HSIs), and Tribal Colleges and Universities (TCUs).

Victor R. McCrary, Jr. is the first Vice President for Research and Economic Development at Morgan State University, Baltimore, MD. He is a change agent and serial innovator responsible for developing a comprehensive research strategy, fostering cross-disciplinary research, expanding research programs via engagement with federal and state agencies, increasing the University's intellectual property portfolio, and positioning Morgan State as Maryland's Public, Urban Research University. Previously, he was the Business Area Executive for Science & Technology at The Johns Hopkins University Applied Physics Laboratory (APL), where he developed technology investment strategies for basic and applied research targeted for national security and space applications. In 2005, Dr. McCrary was selected to the rank of Principal Professional Staff at The Johns Hopkins University Applied Physics Laboratory. He is a former national president of the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE), and a Fellow of the American Chemical Society.

McCrary serves on numerous committees including the subcommittee for the U.S. Air Force Institute of Technology (AFIT), the Intelligence Science and Technology Experts Group of the National Academies of Science, Engineering and Medicine, the advisory board for electrical and computer engineering at The Citadel, the board of the Maryland Innovation Initiative of the Maryland Technology Development Corporation (TEDCO), and the PubMed Central National Advisory Committee for the National Institutes of Health.

He has authored or co-authored over 60 technical papers and co-edited two books. He is blessed to have received a number of honors and awards during his career including: Most Promising Black Engineer in 1990; co-recipient of the U.S. Department of Commerce's Gold Medal in 2000; the 2002 NOBCChE Percy Julian Award; in 2005, he was featured in Science *Spectrum* Magazine as one of the Top 50 Minorities in Science, and elected to the 2007 DVD Association's Hall of Fame. In 2011, he was honored as Scientist of the Year by the Annual Black Engineer of the Year Award-STEM Conference. In 2015 he received the Alumni Award for Research Excellence from The Catholic University of America.

He is married to Captain Mercedes Benitez-McCrary (USPHS), and they are blessed with two children, Francesca and Maximilian. McCrary is a member of the National Science Board's Class of 2016 – 2022

Chairwoman COMSTOCK. Thank you. And I now recognize Dr. Sands, and I understand you have a video, so I look forward to that.

TESTIMONY OF DR. JOHN SANDS, DEPARTMENT CHAIR, COMPUTER INTEGRATED TECHNOLOGIES, MORAINE VALLEY COMMUNITY COLLEGE; DIRECTOR AND PRINCIPAL INVESTIGATOR, CENTER FOR SYSTEMS SECURITY AND INFORMATION ASSURANCE

Dr. SANDS. Yes, good morning, Chairwoman Comstock and Ranking Member Lipinski. I'd like to start with a short video that talks a little bit about our programs and highlights one of our students.

[Video shown.]

Dr. SANDS. I'm here today to share my knowledge and opinion on how apprenticeship programs can address the growing gap in the country's technical workforce. I'd like to present a few potential approaches to increase the quality and participation rate of apprenticeship programs in technological areas like cybersecurity.

Over my career, one of the areas of the workforce development I've been most involved in is the study and implementation of effective programs to increase student awareness of critical technology fields. Both as a Professor and Principal Investigator, I have led teams to develop new and innovative career awareness programs. These programs present students with self-directed opportunities to explore interesting technical jobs. The exploration also requires students to examine the typical roles and responsibilities associated with each position. These programs also enable students to review salaries, job credentials, and potential career pathways.

Another area is expanding partnerships and apprenticeship programs. Moraine Valley Committee College has been successful in building partnerships in which local businesses benefit from a continuous pool of qualified applicants. Students benefit by gaining experience and learn workforce skills that are difficult to replicate in the classroom.

One example of the successful program would be the partnership between Moraine Valley Community College and ESPO Systems. In the fall of 2017 ESPO Systems was nominated for the Illinois Community College Trustee Association Business and Industry Partnership Award. Representatives from both ESPO Systems and Moraine Valley focused on building apprenticeship programs that provide students with a meaningful and relevant workforce experience. This program also serves dozens of students, most of which go on to full-time employment. ESPO Systems and Moraine Valley staff meet each semester to plan, review, and evaluate the program.

One of the other areas that I think is important is establishing apprenticeship program standards. As a rash of data breaches continue to make headlines, businesses have gained greater interest in working with academia and federal agencies in adopting national standards. The NSA/DHS Centers for Academic Excellence program is a good example. This program establishes curriculum requirements, student learning assessment, and a series of institu-

tional requirements. This program serves as a great mechanism to expand apprenticeship programs for the cybersecurity industry.

Another area is establishing national credentials earned by completing an apprenticeship program. I believe there is strong support for establishing a national credential that would be directly linked to students' successful completion of a recognized apprenticeship program. The cybersecurity industry is well-organized to adopt this type of program that could be directly associated with one of the two national programs that are operated by federal agencies, and those two programs would be the CyberCorps Scholarship for Service program, which is funded through the National Science Foundation; and the other would be the Centers of Academic Excellence in Cyber Defense, which is funded by the National Security Agency and Department of Homeland Security.

I also want to stress the importance of community colleges. I would like to highlight the unique role community colleges can contribute to establishing a better national network of apprenticeship programs. Community colleges, as the name indicate, belong to and serve their communities. Students attending community college programs are looking for inexpensive and efficient pathways to new careers and academic opportunities.

Community colleges provide their communities with the nurses, healthcare workers, heating and air-conditioning technicians, automotive technicians, information technology specialists, just to name a few. Community colleges have a close relationship with the current technology programs at their local high schools and can provide students with an early awareness of career opportunities in technical fields. Any expansion of apprenticeship opportunities should leverage community colleges in their unique position within communities across the Nation.

That concludes my testimony. Thank you.

[The prepared statement of Dr. Sands follows:]

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE & TECHNOLOGY

February 7, 2018

Testimony of John L. Sands

Professor at Moraine Valley Community College and Principle Investigator/Director of the Center for Systems Security and Information Assurance (CSSIA) an NSF/ATE Center

Summary

As stated in the Presidential Executive Order Expanding Apprenticeships in America, the American Education System and Workforce Development Programs are in need of reform and federal investment. Over the last 20 years, the United States has experienced a shift from career and technical programs taught in high schools to college prep. Although this shift has resulted in more opportunity for students to gain a head start in earning a college certificate or degree, the elimination of career and technical programs has resulted in a workforce shortage in many career and technical fields. This shortage most impacts the high-level technicians. An example of this would be cybersecurity analyst, electrical system engineers and several technical positions in the manufacturing sector.

Moraine Valley Community College received a National Science Foundation/Advanced Technological Education Program (NSF/ATE) grant award in 2003 to study the cybersecurity workforce needs. The grant specifically funded our research of the nation's academic capacity to address the growing shortage of highly skilled cybersecurity professions. I currently serve as the Principle Investigator and Director for the Center for Systems Security and Information Assurance (CSSIA). Over the last 15 years, the National Science Foundation has funded our Center to identify barriers institutions face in developing quality cybersecurity technician programs. Our research has continually identified five major barriers institutions face in trying to meet the nation's capacity for cybersecurity professionals. These barriers include:

- Relevant and up to date curriculum
- Faculty shortage and faculty credentials
- Safe environments and laboratories for students to use the tools of the trade
- The establishment of effective apprenticeship programs
- The ability to diversify students in cybersecurity programs

The funding has enabled our Center to train over 6,000 K-12 and college faculty and provide instructional content that reflects the changing skill sets and knowledge required of today's cybersecurity technician. The CSSIA Center has developed over 400 labs that reflect current tools and technologies required of today's cybersecurity workforce. The Center distributes these labs to over 370 schools across the nation through our web portal. The Center also operates a virtual teaching and learning center that enables students to use real tools in a safe environment without impacting their institutions production network. The Center has also worked with organizations like The Association of Computer/ Information Sciences and Engineering Departments at Minority

Institutions (ADMI) in an effort to build their cybersecurity program capacity and produce more minority and women professionals in the cybersecurity workforce.

My experience in working with business partners that serve on our institutions advisory committees is that these positions are critical to our nation's economic strength. Our business partners recognize the need to re-establish strong career and technology programs both in the high school and community college system. There are several examples in which businesses are working closely with academic institutions to develop standalone apprenticeship programs designed to attract talented individuals to fill the type of technical positions in the highest demand. An example of such programs would include *Steelworkers of the Future*.

Steel companies dismantled their apprenticeship programs decades ago, but ArcelorMittal put a new spin on the old ways when a maintenance technician shortage was critical to their U.S. operations. *Steelworkers for the Future* has been around since 2007. That was when the steel industry emerged from years of consolidation and plant closings. The technicians who repaired and built machines, who could weld together a replacement parts on a dime or troubleshoot a communication glitch between machinery, were retiring and no one had the training to replace them in this very specific and complex job.

The steel industry realized they were losing in excess of 200 experienced mechanics and electricians per year. At this rate, the retirement of skilled individuals was beginning to impact their ability to maintain current production needs. ArcelorMittal developed a curriculum with partner colleges that includes coursework in welding, metallurgy, physics, hydraulics and pneumatics, as well as a sprinkling of liberal arts classes. During their two years of schooling, students who qualify for the program can take up two eight-week internships at their local plant, essentially working alongside an experienced technician as an apprentice. This experience changed the perception of students of the current work environment for the modern steel worker.

During their schooling and their apprenticeship, candidates are not yet employees. To make it through the hiring process, they are required to complete their studies and pass an entrance exam, which they can take during their apprenticeship. This apprenticeship offers $20.40 an hour for a 40-hour week. The average pay for technician jobs is $90,000 annually.

TESTIMONY

I am here today to share my knowledge and opinion of how apprenticeship programs, internships and residencies can address the growing gap in workforce needs and our nation's capacity to prepare students for these positions. I would like to share four potential approaches to increasing the quality and participation rate of apprenticeship programs in technological areas like cybersecurity.

Career Awareness

Over my 30 year career, the one area of workforce development I have been most involved in is the study and implementation of effective programs to increase student awareness in current critical technology fields. The majority of research in the area of student career awareness reflects that the absence of formal career awareness programs in our academic institutions result in greater shortages of students pursuing careers in technical programs. Both as a professor and resource center principle investigator, I have led teams in developing new and innovative career awareness programs. These programs present students with a self-directed opportunity to explore interesting career and technical jobs. The exploration also requires students to examine the typical roles and responsibilities associated with each position. These programs also provide a review of national resources that define typical salaries, job credentials and potential career pathways. One of the programs developed by the Center has been adopted by the Cisco Networking Academy. Last year, the course was used in over 4,000 classrooms and exposed thousands of students to potential careers that otherwise might not have been an option. This is just one example, however, there is a need or more national efforts to increase career awareness for students in K-12 institutions.

Increasing Business Investment and Apprenticeship and Internship Opportunities

Another important aspect of building effective cybersecurity programs is partnering with local businesses and organizations to build local apprenticeship and internship programs. Moraine Valley Community College has been successful in building these partnerships in which local businesses benefit from a continuous pool of qualified applicants and students who are able to gain experience and learn workforce skills that are difficult to replicate in the classroom. One example of a successful program would be the partnership between Moraine Valley Community College and ESPO Systems. This partnership represents the potential impact of well-designed apprenticeship programs. In the fall of 2017, Mr. Nick Stricker, a ESPO Systems representative, was nominated for the Illinois Community College Trustees Association Business/Industry Partnership Award. For a number of years ESPO Systems has hosted 32 student interns, 16 of whom have been hired as full-time employees.

Representatives from both ESPO Systems and Moraine Valley were focused on building an internship program that provides students with a meaningful and relevant workforce experience. This could only be achieved if both partners agreed upon the foundational skillset required for students entering the internship program. ESPO Systems and Moraine Valley representatives agreed upon a pathway to prepare students to gain the greatest benefit from their internship

experience while providing real value to the employer. This model has proved to be successful in that many of the intern participants have gone onto become full-time employees of ESPO Systems or one of their client's businesses. The result is each semester new opportunities are created for student internships.

ESPO Systems and Moraine Valley staff meet each semester to plan, review and evaluate the internship program. In addition, ESPO Systems serves on the Employer Advisory Committee. They also sponsor college events and student competitions.

Establishment of Industry Sponsored/Regulated Apprenticeships and Internships

As the rash of data breaches continue to make headlines, businesses have gained greater interest in working with academia and federal agencies in adopting national standards and recognizing schools that gain recognition from meeting the established standards. The National Security Agency and Department of Homeland Security established the National Centers of Academic Excellence in Cyber Defense. This program establishes curriculum requirements, student learning assessments and a series of institutional requirements. The CAE-CD program has established a national benchmark to identify institutions that achieved excellence in operating cybersecurity programs. Moraine Valley Community College was one of the first five two-year colleges in the nation to receive this designation. The CAE-CD designation process would serve as a great mechanism to expand quality apprenticeship programs for the cybersecurity industry. The program requirements could be expanded to require and recognize model apprenticeship programs. This program provides needed resources and funding that could be used to invest in building a national network of cybersecurity apprenticeship programs.

Establishing National Credentials Directly Linked to Participation in Internships and Apprenticeships

Based on my experience in working with academic institutions that teach cybersecurity programs, I believe there is strong support for the establishment of a national credential that would be directly linked to student's successful completion of a recognized apprenticeship or internship program. Many other industries that require practical technical skills have established these types of apprenticeship credentials. There are many examples of these credentials in the medical field. The cybersecurity industry is well organized to adopt a similar program that could be directly associated with one of the two national programs that are operated by federal agencies. CyberCorps (R): Scholarship for Service (SFS) is a unique program designed to increase and strengthen the cadre of federal information assurance professionals that protect the government's critical information infrastructure. This program provides scholarships that may fully fund the typical costs incurred by full-time students while attending a participating institution, including tuition and education and related fees. The scholarships are funded through grants awarded by the National Science Foundation (NSF). This program could leverage current internship opportunities with a nationally recognized credential that students could earn by successfully completing an apprenticeship or internship program with a federal, state or local government agency. The

NSA/DHS CAE-CD program could also be used to expand a nationally recognized credential earned by students participating in recognized apprenticeship programs in the private sector.

Concerns Associated with a Nationally Recognized Apprenticeship Credential

The establishment of a national apprenticeship program with nationally recognized credentials would need to be designed so that no potential student is left behind and that the program would be made available to all citizens regardless of age, sex, race and other factors. There are many successful examples of apprenticeship program in Europe and Asia that have been very efficient in meeting workforce demands but have resulted in older citizens being locked out of potential apprenticeship opportunities. The rigidness of these programs creates a one-shot opportunity for students to participate and those that miss this opportunity have little chance of ever participating in the program afterwards.

The Role of Community Colleges

As a 30 year employee of the community college system, I would like to highlight the unique role community colleges can contribute to establishing a better national network of apprenticeship programs. Community colleges as the name indicates belong to and serve their local community. Students attending community college programs are looking for an inexpensive and efficient pathway to new careers and academic opportunities. Community colleges provide their local communities with the nurses, health care workers, heating and air conditioning technicians, automotive technicians, information technology specialists and cybersecurity specialists to name a few. Community colleges have close relationships with the career and technology programs at their local high schools and can provide students with an early awareness of career opportunities in technical fields. Many of the adjunct faculty that teach at community colleges come from the local workforce. These individuals enable community college career and technical programs to build strong partnerships with our local businesses. Any expansion of apprenticeship opportunities should leverage community colleges and their unique position within communities across the nation.

BIOGRAPHICAL SKETCH

NAME	POSITION TITLE
John Sands	Department Chair/Professor Computer Integrated Technologies (CIT)
sands@morainevalley.edu	

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	MM/YY	FIELD OF STUDY
Colorado State University	Ph.D.	05/08	Education
Governors State University	M.A.	05/01	Human Performance and Testing
Chicago State University	BA	05/92	Communications

Personal Statement

John Sands has over 30 years of experience in education and workforce research in the areas of data communications, manufacturing technologies, information technology, information security management and cybersecurity. He currently serves as the department chair and professor of information technology at Moraine Valley Community College. John also serves as the Principal Investigator/Executive Director of the Center for Systems Security and Information Assurance (CSSIA), an NSF/ATE National Support Center. John's team has studied the technology workforce needs both in the local Chicago metropolitan region and nationally as the Principal Investigator of CSSIA. He holds a Ph.D. from Colorado State University and several industry certifications.

As a department chair, full time faculty member, and academic researcher, he has developed and taught numerous online technology courses using an integrated virtual teaching and learning environment. Dr. Sands has served as the executive director of one of the most successful Cisco System - Networking Academy Training Centers in the country. John also possesses a very strong background in developing and implementing online curriculum for both students and faculty and has been the recipient of several awards in the area of innovation and teaching. Professor Sands also has received several academic awards including the Master Teacher of the Year, Innovator of the Year and the Career Pathways Partnership Excellence Award - Best Dual Credit Program.

Positions and Honors

Department Chair Computer Integrated Technology (CIT) Department (1996-Present)

Department Certificates Programs:
Computer Technician; LAN Technician; Network Administrator; Microsoft Associate; Cisco Network Associate; Cisco Network Professional; Mechanical Drafting Associate; Autodesk Inventor Specialist; AutoCAD Specialist; Architectural CAD; Mechanical and Fluid Power Maintenance; Fluid Power Technician; Electronics Technician; Electronic Controls Technician; Industrial Controls Technician; PLC Technician; Mechanical Drive Technician; Industrial Maintenance Technician; Manufacturing Intern; Plant Engineering Mechanic; Computer Support Associate; Network Security Associate; Network Security Specialist;

Department Associate of Applied Sciences (A.A.S.) Degree Programs:
Computer and LAN Tech; IT Security Specialist; Voice and Data Specialist; Mechanical Design Technology; Mechatronics Technology; Electronic Computer Controls Tech; Integrated Systems Technology; Computer Graphics Imagery

Responsibilities:

- Managed the submission and approval process for college AAS degree and certificate programs.
- Classroom instruction; curriculum development, instructional materials and classroom evaluation
- Manage department schedules, budgets, faculty hiring, articulation programs and program evaluation and accreditation processes.

Grant Management and Researcher (1996-Present)

- Principle Investigator for the Center for Systems Security and Information Assurance (CSSIA) NSF Award #1465163
- Established the CSSIA National Faculty Development Training Academy
- Co-Designed the CSSIA Virtual teaching and Learning Environment
- Principle Investigator for the Scholarship for Service (CyberCorp) Capacity Building Grant Award #1623591 National Science Foundation
- Principle Investigator for the CAE National Security Agency Award: H98230-16-1-0347
- Principle Investigator for the Cybersecurity National Action Plan Investment and Expansion of CAE-C Programs (CNAP) National Security Agency Award: S-004-2017
- Principle Investigator for the National K-12 Career and Technical Education Programs of Study Award: H9230-17-1-0436 National Security Agency Award # S-004-2017
- Co-Principle Investigator for the GenCyber Award # H98230-17-1-0254
- Principle Investigator for the Scholarship for Service (CyberCorp) Capacity Building at Purdue University Northwest Grant Award #1754090-DGE SubAward# 4101-84307 National Science Foundation

Organizational Researcher for Cisco Learning Institute (2008-2010)

Responsibilities:

- Studied teaching and learning strategies, trends and challenges faced by the Cisco Networking Academy community
- Studied the changing information technology workforce needs and requirements
- Studied student performance metrics in an effort to improve classroom methods, instructional materials, teaching tools, assessment instruments and employability

Director – Cisco Area Training Center (1998-2012)

Responsibilities

- Served as Cisco System Network Academy Program training provider and Quality Assurance Partner in Illinois
- Provided technical and academic assistance to all Cisco Academies in the Midwest region
- Served as one of five CATC's in Wireless Technologies, Network Security and CCNP Programs
- Developed evaluation and assessment reports for Cisco Area Account Manager in the Midwest
- Served as the lead instructor for faculty development and instructor certification classes

Other Positions or Research

Responsibilities

- Adjunct faculty member Northwestern University Information Security Management MA Program
- Served on the ISC^2 National Advisory Committee to review and update industry certifications
- Served as a curriculum developer and test writer for the Cisco Academy Program
- Served as the external evaluator for the University of Boise Information Technology Program
- Active Duty United States Navy, Gas Turbine Specialist

Academic Awards

- Moraine Valley Community College - Master Teacher (1998)
- Moraine Valley Community College - Innovator of the Year (1990) (1999) (2005)

Information Technology Certifications

- Certified Cisco Network Professional CCNP, Cisco Certified Academy Instructor CCAI (Routing & Switching)
- Microsoft Certified Systems Engineer MCSE
- CompTIA A+, Network+, Security+
- Certified Information System Security Professional (CISSP)

Chairwoman COMSTOCK. Thank you. And I now recognize Mr. King for his testimony.

TESTIMONY OF MR. MONTEZ KING,
EXECUTIVE DIRECTOR,
NATIONAL INSTITUTE OF METALWORKING SKILLS

Mr. KING. Thank you, Chairwoman Comstock and fellow members, for inviting me to speak out about innovative work training programs.

I want to start out with some statistics. I don't want to create an echo chamber because of my panelists here, but I need to say that the stakes are high. And I would like to start with about 3.5 million jobs are likely to be needed within the next decade. And with the skills gap, there's likely to be about 2 million of those jobs unfilled. And another really interesting statistic is only 16 percent of all American high school seniors are either proficient in mathematics or are interested in STEM careers. That's significant. So when we talk about building training programs, you can have the best program in the world but if you don't have any bodies in there, it doesn't matter. So you have to increase the interest.

So how do we do that? I'm going to move to my next slide. This leads into my next slide.

[Slide.]

Mr. KING. And just bear with me because everyone has their own way of recruiting, and I recruit people all the time. I'm always looking for someone to enter into the skilled workforce. So the Walking Dead syndrome is the truth in reality. It is—now, think about—this is a popular series that's on TV. And the series framework is based on an overwhelmingly large population of zombies searching for a small majority of flesh for the survivors. This is a small amount of survivors and you have all of these zombies, millions, millions with maybe 1,000 survivors. And they're all looking for the same thing. And this is a striking parallel to our college campuses. It extremely—it really is.

Now, think about all of those individuals on the college campuses going for jobs—they're trying—they're planning for jobs that either won't exist when they come out of school or rapidly evolving or it's not within that skill frame where most of the jobs will—we've heard statistics where you show that most of the jobs will be for—won't require a four-year degree, but most of our students or our kids are going for four-year degrees. So it's extremely important to speak the reality and truth to our young people so that they know the truth. And it really works when we talk to these young people about the Walking Dead syndrome.

So how do we train? And you got to—we've got a look at today's economy where the jobs are more integrated, cross-discipline, technology-driven so when we build these STEM education training programs, I believe we need to focus on the work-and-learn opportunities, more work-and-learn opportunities. We also need to focus on creating an education pathway that supports students from middle school through their career advancement.

And this leads into my next slide.

[Slide.]

Mr. KING. So when you look at this slide, you see a work-and-learn career pathway model where we have our gateway, how do we get in, and then we have our goal. And then you can see credentials as we get to our goal as the industry-recognized credentials. Now, if you look at the vertical path, you see that's a straight upward path, training, education, go to college, right? Everyone—you're taught to go to college. And then you have on the horizontal hands-on experience. You have those individuals that maybe come out of high school and just go with hands-on experience. But what we're seeing is neither path is necessarily the best path. We need to go on a diagonal path where you're getting education and hands-on experience contemporaneously interwoven together. So this is what we're seeing as a successful model, maybe not for everyone but it can help with those—that large pool of opportunities that exist and that are not being filled.

So I'll go into my last point, which is industry engagement. Industry has to identify the standards are. It's not the schools, it's not the education community. We are to follow what industry says is needed. And so how do we do that? So when we look at industry-recognized credentials, industry-recognized standards, that is the key. The standards are the foundation that are actually written by industry. Industries are writing down what their needs are and then developing credentials around those standards to measure individuals against the standard.

So if we use the credentials as an adhesive or a connector throughout the careers, for example, for me, I got started in middle school. Someone gave me the Walking Dead syndrome, maybe in different words, but they gave me that syndrome or they talked to me about it. And as I moved through my career, I earned the credentials and I had the work experience, making me a straight-A student through the entire process.

So I want to thank you again for having me, and I look forward to some of the questions coming through.

[The prepared statement of Mr. King follows:]

Testimony of Montez King, Executive Director, NIMS
To the Subcommittee on Research and Technology of the Committee on Science, Space, and Technology

February 15, 2018

Good Morning, my name is Montez King and I am the executive director of NIMS, which provides skill standards, credentials, and training frameworks for advanced manufacturing and related industries. I want to thank Chairwoman Comstock and fellow members of the Subcommittee for inviting me to speak about innovative workforce training programs that create a pathway to robust and successful STEM careers.

I want to start by emphasizing that the stakes are high. Over the next decade, 3.5 million manufacturing jobs likely need to be filled. The skills gap is expected to result in 2 million of those jobs going unfilled.[1] Contrast that economic growth with the fact that our talent pipeline is unsure **and** 10,000 baby boomers leave the workforce everyday.[2] There are 5.5 million disconnected young people between 16-24 who are currently out of school and not working. That is 1 in 7 young people.[3] Only 16 percent of American high school seniors are proficient in mathematics and interested in a STEM career.[4]

This leads into my first slide: **The Walking Dead Syndrome**
Most of us are familiar with this popular series. The framework is based on an overwhelming large majority of the world's population turned into zombies, wandering the earth in search of flesh from a few remaining survivors. This is a striking parallel to our college campuses. Our overwhelming large population of youth are wandering campuses like those zombies, in hopes of getting jobs that are scarce or rapidly evolving.

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[1] "The Skills Gap in US Manufacturing: 2015 and beyond," The Manufacturing Institute and Deloitte, 2015.
https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-pip-the-manufacturing-institute-and-deloitte-skills-gap-in-manufacturing-study.pdf
[2] Pew Research Center population projections:
http://www.pewsocialtrends.org/2010/12/20/baby-boomers-approach-65-glumly/

[3] Opportunity Nation: https://opportunitynation.org/disconnected-youth/
[4] U.S. Department of Education: https://www.ed.gov/sites/default/files/stem-overview.pdf

In today's economy, jobs are becoming more integrated, cross-discipline, and technology-driven. We can't just prepare kids for the jobs we have open today—we have to prepare them for the jobs that don't yet exist. As we build STEM education and training programs, we *must* focus on three key elements: expanding work-and-learn opportunities across the economy, creating education pathways that support students from middle school through career advancement, and engaging industry in the design and deployment of career-related education and training.

This leads into the next slide: **The Work and Learn Career Pathway Model**
This slide illustrates three (3) career pathways towards the same career goal, where work-and-learn yields the highest probability of success for students needing to prepare for 21st century STEM careers. No longer can students expect to land and be successful in a job if they are on a straight **vertical** academic path (i.e. just go to college). Conversely, students today need more than a **horizontal** path of hands-on experience. STEM students need BOTH education and hands-on experience contemporaneously interwoven together. This work and learn model is a collaboration of academics and hands on experience, maximizing your probability of success through a **diagonal** path.

Work-and-learn programs are proven models of workforce preparation and successful student learning because they connect theory-based classroom instruction with career development and integrate structured education and training with work experiences. Examples of work-and-learn programs include apprenticeships, internships, work-study, mentorship, job shadowing, and co-ops. Work-and-learn programs can be applied at multiple career levels and job functions and may be tailored for participants ranging from middle school students to mid- career employees. Work-and-learn programs allow employers to help students and workers gain and demonstrate necessary "hands-on" skills, competencies and other common employability skills (e.g., teamwork and dependability) that are necessary for workplace success.

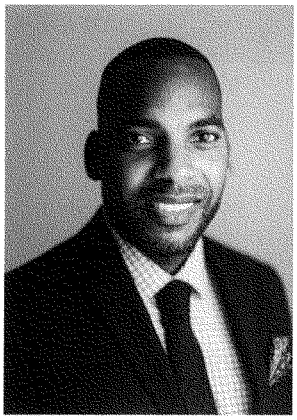
What's more is that work-and-learn programs can connect to form a seamless pathway. An example of this seamless pathway is for a NIMS precision machining student. Students can complete a work-study program in high school, so they graduate with a diploma, and two

industry-recognized NIMS credentials in machining. These credentials enable students to transition into an apprenticeship program, which provides them with additional education and college credit, industry-recognized credentials and paid work experience. Industry-recognized credentials—which are competency-based—validate a students learning and acquisition of knowledge and skills, and act as the connector from and between education and training programs and the workplace.

The final key component of STEM education and training is industry engagement and leadership. Simply put, we cannot design education and training programs without industry guiding us. The voice of employers is imperative in educating individuals to industry standards and ensuring training programs are adequately preparing individuals for the workplace. Industry-recognized skill credentials are vehicles for ensuring the link to industry.

In conclusion, work-and-learn pathways incorporating industry-recognized credentials are the surest way to prepare the STEM-ready workforce of the future. I encourage policymakers, employers, educators, and workforce professionals to support these innovative approaches that impact not only student success, but also the prosperity of local communities, and our nation's economic competitiveness.

Thank you for your time.



Montez King
Executive Director
NIMS

Montez King is the Executive Director of NIMS, developing national standards and competency-based credentials in manufacturing trades. Montez is responsible for overseeing the administration, programs, and strategic plan of the organization. Prior to joining NIMS, Montez served as Training and Technology Manager for Magna International, one of the world's largest OEM automotive parts manufacturer. He launched his career at Teledyne Energy Systems as a Machinist Apprentice, where he earned his Maryland State Journeyperson Machinist certificate. Montez's academic background includes a B.S. degree in Information Technology and M.ED degree in Adult Education from the University of Phoenix. In October 2017, Montez was appointed to the President's Task Force on Apprenticeship Expansion.

Chairwoman COMSTOCK. That captures everyone's imagination. Thank you.

Dr. Bardo, follow-up that act, right?

TESTIMONY OF DR. JOHN BARDO,
PRESIDENT,
WICHITA STATE UNIVERSITY

Dr. BARDO. Well, thank you very much, Madam Chairwoman, and thank you for—everybody for having me here today. And the timing couldn't have been better in terms of following Mr. King.

For those of you that don't spend all day thinking about Wichita, which I can't imagine any of you sitting up there wouldn't be doing that, Wichita is the third-highest percentage—it has the third-highest percentage of engineers in the workforce compared to San Jose and Houston. And we are very dependent on technology-based exports. In fact, to set up our programs when I came back home to Wichita, I did a study of the structure of the Wichita economy. We're very tightly tied to Dallas-Fort Worth, and we're very tightly tied to the I–35 corridor. We also export to five or six places in the United States, export goods are where you make your money, and then we export overseas.

We knew that those were very important things to know about the economy, but how does that play out within individual industry? So we at the university started a blueprint for regional economic growth, which was an analysis with business of their needs. We didn't go in and tell them what they needed; we asked them. And we identified eight areas where the economy of greater Wichita could grow, and our goal as a university is to support each of those areas over time as funds become available.

You may also not know that Wichita has—Wichita State has a very long tradition of working with business and industry. We obtained our first major gift of the year—I was born in 1948, which was a wind tunnel given by Beech. We are now second in the United States in the percent of research money funded by industry. So we're very serious about our relationships with industry.

And one of the points I want to make with you today is that that tie between industry research and education is absolutely crucial if you're going to be able to really make a difference for the capacity of the United States to build STEM and to build STEM-based industries.

We also, as a university, are very prone to experiment. We've been prone to experiment over the course of decades—this isn't new—and we're very excited about the fact that we have a modified apprenticeship program going at a four-year university. Wichita State is what is in the vernacular known as a research II, which means that we are not the highest level of research but we're second. And we have a modified apprenticeship program. We started it—they tested it—with an aircraft industry. There were going to outsource a large engineering project to India. We convinced them to allow our undergraduate students to do it. It came in on time, better engineered, and while they weren't hiring, they hired 35 percent of the students who worked on the project, and 83 percent of the students stayed in the labor shed. A few others left. Two went

to—one went to med school and one went to get a Ph.D. in engineering, and we're okay with both of those outcomes.

We also were in the process of amalgamating a technical college into the university, Wichita Area Technical College July 1 will become Wichita Tech, WSU Tech. Why are we doing that? There are so many people who have hands-on skills who want to learn, who want to be part of the economy, want to be part of STEM, but they don't want to take on a 15-week course. They don't want to take on a 120-hour degree. And so what we're trying to do is to find ways of moving those students into the workforce and the model you were using, moving them into the workforce and building their capacity through offering short courses, through offering degrees, through offering certificates and building their capacity over time so that they can lead in their field.

If they want to be a welder, if they want to be a sheet metal worker, we want them to do that. If they want to be a sheet metal worker supervisor, we want them to do that. If they want to be a designer of new aircraft, we want them to do that.

So, Madam Chair, to cut this short, it's time for Congress to act as it did in the '80s. The *Bayh-Dole Act* changed the future of higher education in the United States. I believe it's time for Bayh-Dole II, and I believe this Committee is the committee that can make that happen. Thank you very much for having me here today.

[The prepared statement of Dr. Bardo follows:]

Dr. John Bardo
President, Wichita State University
February 15, 2018 testimony to the U.S. House of Representatives
Committee on Science, Space and Technology, Subcommittee on Research and Technology

"Innovations in STEM Mentoring, Training and Apprenticeships"

Madam Chairwoman and members of the committee, thank you for the opportunity to share what we at Wichita State University are doing to improve STEM education and to more closely tie our educational approach to the skills and economic needs of our metropolitan region and the state of Kansas.

My 40-year career in higher education has taken me from my home state of Ohio to Kansas, Texas, Florida, Massachusetts and North Carolina before returning to Kansas six years ago to become president of Wichita State.

Today I'm sharing the key considerations that led us to re-think how our university approached increasing the quality and quantity of STEM-educated graduates in the workforce. These changes that have attracted international companies to our campus have been made at a university in the very center of America's heartland, not on the East or West Coast. While Congress will never do so, it is crucial that we not let others write off large sections of our country. Innovations in industries as diverse as aviation, energy and fast food have come from Wichita and can continue to do so. As a university, we are trying very hard to help spur competitiveness, so we have charted a path that is very focused on higher education deeply grounded in applied learning and research.

The passage by Congress of the Bayh-Dole act in 1980 represented a watershed event for higher education and the impact research universities could have on discovery and job growth. Bayh-Dole provided formal recognition of the importance of universities in the technology transfer that would increasingly propel the national and global economy. Thirty-eight years later, the foresight of Bayh-Dole cannot be overstated. It marked a formal beginning of the movement of higher education from the sidelines, as that place where you prepared to "enter the real world," to higher education becoming one of the major pillars of America's future prosperity, security and quality of life.

It has become clear since Bayh-Dole that higher education is a crucial component of American economic success and future. University education and research play a pivotal role in our nation's global competitiveness. We at Wichita State University take this responsibility very seriously and we are fully focused on our role in securing the future. Our strategic plan is straightforward in its vision and direction:

- Our core vision is for Wichita State University is to be internationally recognized as the model for applied learning and research.
- The mission of Wichita State University is to be an essential educational, cultural and economic driver for Kansas and the greater public good.

This vision and mission are inspiring Wichita State University to focus on becoming a new American university driven by the emerging educational needs of a much broader range of students than traditional universities, as well as concentrating on how we can increase global competitiveness for the benefit of the people, the region and the state we serve. In short, we are driven to provide employment

opportunities, prosperity and economic inclusion for those living in southcentral Kansas. The focus of the remainder of my testimony will be on how we are evolving and implementing this mission and vision with specific regard to STEM and the economic competitiveness of our part of the country, as well as some major lessons learned that may be beneficial to this committee and other universities.

One size will never fit all: Education linked to location and economic potential

In the abstract, applied education that incorporates STEM-focused internships, mentorships and apprenticeships clearly improves outcomes for students in these areas. However, when moving beyond the abstract, what to implement and how to implement it becomes much more difficult and nuanced. What might be very appropriate in Huntsville, Alabama may not fit well at all in Wichita, Kansas.

We have learned that programs to improve STEM education have to be designed and implemented with an integrated approach that involves economic analytics, economic structural analysis and on-going feedback and assessment.

From a student's perspective, STEM courses are challenging. He or she needs to be able to see the value, or the work won't be seen as worth the effort. Increasing the number of students in STEM education, and the quality of that education, has to be linked to the student's goals and life interests. In many cases, those interests have more to do with family, community and non-academic pursuits than in long-term, challenging, academic programs. We have to be prepared to answer the student's questions about why education in a STEM field is worth the effort.

At Wichita State, rethinking education began with a contextual analysis

There were four major components to WSU's contextual analysis:

1. Regional economic structural analysis
2. Trade good destination analysis
3. Specific metropolitan economic analysis
4. Blueprint for Regional Economic Growth

These four component analyses were used to establish a context for modifying the university's approach to education, R&D and its relationship with its broader community.

Regional economic structural analysis

A number of studies of the restructuring of both the national and global economies have documented the shift of economic outputs to major metropolitan areas, with these major metros acting as hubs or "economic centroids" for broader regions of production, distribution and economic networking.

Globally, there are approximately 40 such hubs, with 10 of them in the U.S. Third-party analyses of Wichita show that it is a component of one of these 10 "super-regions," part of the "I-35 Corridor." The economic centroid of this super region is increasingly focused on Dallas-Fort Worth and the "Texas Triangle," with cities in Oklahoma, Kansas and western Missouri increasingly tied to that centroid.

Trade good destination analysis

Although services make up a very important part of any economic base, the key driver of new income both for businesses and individuals is the volume and value of goods traded that have their origins within the region. Analyses of Wichita's trade good destinations showed that they largely followed the I-35 corridor, with substantial trade moving to the coasts for export.

Specific metropolitan economic analysis

Bulleted below are some of the most significant findings of the metropolitan economic analysis:

- According to the Brookings Institution, of the largest 100 metropolitan areas:
  - Wichita ranks number 1 in manufacturing jobs as a percent of all jobs, with Wichita having the highest concentration of aerospace manufacturing in the nation.
  - Wichita ranks number 1 in the percentage of jobs involving STEM
- According to the National Science Foundation, Wichita ranks third in the percentage of engineers in the workforce, only exceeded by San Jose and Houston.
- Again, according to Brookings, southcentral Kansas is the most manufacturing specialized region in the U.S, with nearly 18 percent of all jobs in manufacturing.
- Wichita is ranked number three as an "advanced manufacturing hot spot."

These analyses clearly show that Wichita has, in many ways, a higher stake in effective STEM education than nearly any area in the country. While these general rankings and statements provided a backdrop for next steps, designing effective models to undergird the region's future prosperity and quality of life required a much finer and detailed analysis than was available to the community and university when we began this work about five years ago. This led to the development, funding and sponsorship by the university of the regional Blueprint for Regional Economic Growth (BREG).

Southcentral Kansas Blueprint for Regional Economic Growth

The final step in our learning process involved bringing in a national firm that specializes in detailed analyses of potential clusters of innovation that can drive the future economy. The university, with the assistance of this firm, looked in detail at potential economic growth sectors; eight were identified. Business leaders and job creators from these sectors were brought together for multiple meetings where they identified needs, stumbling blocks, trends in their area of business and potential for further development. The eight clusters identified were:

- Advanced Manufacturing
- Advanced Materials
- Aerospace
- Agriculture
- Data Services and IT
- Health Care
- Oil and Gas
- Transportation and Logistics

While many of these cluster titles could fit a large number of metropolitan areas, what BREG accomplished was to localize the clusters so that university programs and approaches can increasingly fit the specific situation within this metropolitan region. Based on the needs defined by enterprises in these clusters, coupled with the more general analyses described above, the university began responding by focusing on critical educational and R&D approaches that could improve the competitiveness in several of these clusters.

It should be noted that this is an ongoing process and the university is committed to continuing to extend its capacities to support these crucial clusters. Finally, it should be noted that the process was

considered of sufficient importance that it is now being sponsored and managed by the metropolitan area's primary economic development group, the Greater Wichita Partnership.

In the next sections, lessons learned from responding to this outside-in approach to development of educational approaches to enhancing STEM will be described. The last section also includes a discussion of some opportunities for federal policy and action that could greatly enhance STEM education and promote the competitiveness of the American economy.

STEM education as part of an ecosystem

One of the major issues facing the greater Wichita area has been the continuing outmigration of educated workers and jobs that are being replaced by lower-wage, lower education requirement positions. According to economic analyst James Chung's work for the Wichita Community Foundation, from 2011 to 2013 the typical household leaving the metropolitan area had earned nearly $71,000 per year, while those moving in averaged approximately $58,000. The net difference also is associated with a drop in educational requirements for the typical position.

It's not enough to produce more highly capable STEM graduates; the university also needs to take a role in strengthening local companies so that our graduates can be employed here.

So, the university has been systematically working to expand the need for those students, especially in engineering, to remain in the region. The Innovation Campus at Wichita State, the broader partnerships with business, the focus on applied R&D relevant to the region, and increasing support for entrepreneurship and innovation, all are part of the university's overarching approach to increase the competitiveness of the region.

WSU has a long history of supporting the local economic drivers and, in turn, being supported by them. Wichita bills itself as the "air capital of the world" and the aviation industry has been, and will remain, the core advanced manufacturing industry in the region. Partnerships between the university and this industry can be traced back to at least 1948 with the donation to the university of the Walter H. Beech Wind Tunnel. These ongoing partnerships are, from our experience, crucial to development and maintenance of the highest quality STEM education. Because of our continuing interaction with business, we have been able to respond to many pressing needs and to design programs that support both the student's education and the industry's ability to compete. A specific example involves creating and implementing a modified-apprenticeship program designed to have high impact on an existing Wichita industry.

Over the years, one of the most pressing problems that we heard across industries with regard to workforce availability and industrial competitiveness was that, on average, newly graduated engineers took two additional years of training on the job before they could contribute to their companies' profitability.

Testing an apprenticeship model

In response, we created and tested a modified apprenticeship model with one of the advanced manufacturers in the community. Using undergraduate students, we were able to digitize the plans for their most important product with an accuracy, speed and cost not matched by their Asian outsourced engineers. Moreover, because of the quality of the work and the ability of the students to work with their existing technical staff, even though they were not intending to hire, they offered jobs to 35

percent of the students, and 83 percent of the students in the program found employment within the regional labor shed. The remainder found immediate employment outside the regional area or entered graduate school. Most importantly, the company estimated that the apprenticeship model reduced a newly graduate WSU engineer's time to contribute to profitability from two years to less than six months.

What this model has shown is that a well-designed apprenticeship program greatly benefits student learning, and it increases the student's value to employers while providing a major benefit for industry. Instead of leaving the local labor shed, the vast majority of students in this test of the model remained in the region and will continue to contribute to both regional economic competitiveness and the area's quality of life.

Applied learning experiences for all students

Apprenticeships and longer-term internships can be important components of an overall strategy for STEM, but thinking differently about how to educate the students on campus also plays a critical role. That is why WSU's strategic plan calls for all students to have applied learning experiences regardless of major. It also is why the university is experimenting with new programs and program design. One possibly unique example of a program that is designed to increase competitiveness is WSU's Master of Innovation Design. This program is based on the concept of "design thinking" and upon completion of the program, it is expected that the student will have a:

- Portfolio, patent application, process or prototype
- Willingness and ability to experiment with their ideas
- Network of individuals and businesses with whom they can continue to collaborate
- Desire to continue to design solutions to problems they identity

Demand for this program already exceeds available resources, but this type of innovative approach to education linked to technology and other forms of STEM can be a crucial part of the infrastructure and ecosystem that produces new businesses which are globally competitive and can drive demand for STEM educated workers within the metropolitan region. This, then, can be an important element in convincing students to take advantage of STEM education so they can have good careers within their communities.

Directly engaging the private sector to enhance education

Starting a process by involving the private sector, non-governmental organizations and other entities outside the university provides a base from which to begin developing educational programming. Maintaining those relationships is critical. The competitive situation in the broader market requires ongoing interactions with business and the job creators so that the models of STEM education can be modified in ways that continue to promote competitiveness and success that supports the community, region and state.

While universities typically have "business advisory councils" or other regularly scheduled meetings with industry leaders, WSU's approach has been both more in-depth and broader. Of specific note is the strong relationship between industry-sponsored applied R&D and development of the university's Innovation Campus.

As was highlighted above, WSU is a national leader in R&D sponsored by industry. This ongoing, meaningful interaction has allowed the university not just to hear about potential changes in the market, but to have strong, continuous relationships with industry that allow for strong support and development of nuanced educational programs that address the rapidly changing business environment. The origin of the modified apprenticeship model was from the applied R&D at WSU's National Institute for Aviation Research. That is an important step, but it also was the origin of a major restructuring of higher education in the greater Wichita region that will, over time, create new programs and new approaches to STEM education.

Combining traditional and technical education providers

In addition to Wichita State University, our area has been served for decades by Wichita Area Technical College. This college provides GED to associate degree education for the people of Sedgwick County, and it has a long track record of success. But, what became clear several years ago was that the changing nature of STEM education and emerging needs of industry were increasingly difficult to meet either by the technical college or by the university.

This recognition resulted in the two entities affiliating. The technical college will be known as WSU Tech, though its formal name, effective July 1, will be the Campus of Applied Sciences and Technology.

Within WSU itself, there is a substantial reorganization under consideration to create jointly planned bachelor of applied science degree programs with WSU Tech. This would allow much better integration of hands-on technology with traditional STEM education and strengthen both institutions' capacities to respond to emerging business conditions.

The following is an example of an opportunity that combines traditional STEM education with technical education and partnering with industry to serve students and community.

Connecting younger students with engineering education and careers

Many of the major technology-based employers in our region (and throughout the world) use CATIA software as the platform for their engineering applications, from design to manufacturing. To prepare students to enter engineering fields, the university worked with Dassault Systemes to make the software available free of charge to the region's high schools. Demand from schools across the area has been high, and students who take the class come to university with much stronger background in engineering design. And, with WSU Tech, the CATIA program can more readily be linked with pre-collegiate technical programs, early entry technical and STEM programs for high school students, and joint planning and programming in the high schools to encourage students to enter STEM fields at a level that fits their interests and abilities.

This approach of linking high schools and STEM fields is increasingly being integrated into the university, especially in the College of Engineering. The college is growing the number of graduates equipped with the skillset, entrepreneurial mindset and experience to advance economic and technological prosperity, health and well-being.

We aggressively promote engineering and computer science through strategies that include direct outreach to students in elementary schools, middle schools, high schools and community colleges; and indirect outreach by training K-12 teachers in a pre-engineering curriculum and by fostering

relationships with high schools and community colleges to ensure smooth, successful transition into our undergraduate programs. Throughout, we bring industry professionals with us to camp and into schools, to provide vivid accounts of career opportunities. The result is four consecutive years of record numbers of engineering and computer science students graduated.

Although there is a great deal more in which Wichita State University is engaged, this testimony now will turn to challenges that have been faced in implementing these new programs and their potential implications for federal policy that needs to be shaped by Congress if America is to achieve its promise for the future.

Considering Bayh-Dole 2.0: university challenges and federal policy implications

- Universities must maintain service to traditional students while broadening their reach to new populations. Rapid change in the higher education system is forcing different ways of delivering educational content, discovery of new knowledge and connecting to industry to solve problems.

  With state and university resources stretched to support existing programming, transition assistance to the new forms of programming would both speed implementation and assist in assuring quality. In part, this transition would be assisted by financial support, but costs could be reduced if federal regulations are eased in other areas so that internal university funds could be repurposed. Reducing the cost of regulations is an ongoing discussion at the federal level and it is an important component of assisting universities in moving to a more modern, connected approach to meeting student needs for a high quality, meaningful education while meeting the challenge of economic competitiveness in critical STEM areas.

- Instituting effective apprenticeship programs require organization, oversight and institutional mentoring, not just mentoring by business. The quality of the student experience in any apprenticeship program or extended internship is crucial to effective implementation. It is not enough to place the student under the "mentorship" of people in private enterprise, since the meaning and use of the student may vary greatly. It is critical, therefore, that any apprenticeship program be designed with specific educational goals directly relevant to the student's education and that the achievement of those goals be monitored and assessed. This requires a great deal more "one-on-one" time by faculty members and is both an expensive and effective form of education. Assistance in implementing these programs, if they are indeed a high national priority, would be of great value.

  One of the lessons of our experience with the fledgling apprenticeship program is that "clustering" apprentices within businesses provides a more meaningful experience for students and better results for the business. This clustering also reduces the cost to the university of supporting the program since a faculty member can supervise the cluster of students more effectively and efficiently than scattered individual students. While this is not always possible or desirable, and especially if the apprenticeship is with a small business, policy that encourages clustering and joint business and university planning would be of great benefit.

- There is very little incentive for faculty members to take on these intensive roles given traditional reward systems in most institutions. University faculty members at research universities are generally rewarded through prestige (the perceived value by colleagues of their research) or by salaries and titles tied to traditional teaching, research and service. Implementing new models of education linked to broader community need could be greatly benefitted by national recognition that focuses specifically on emerging needs, especially related to STEM. A national "fellows" program, grants only available to institutions that are committed to enhancing and enriching education within a context of applied R&D meaningful to their location and mission and similar programs could be of substantial value in signaling to the higher education community that the need to refocus is real, of critical national interest and a high priority.

- There is little to no recognition of the strong ties between regionally relevant applied R&D and effective programs to enhance students' education through applied learning, apprenticeships or extended internships. WSU's apprenticeship program has its roots in the university's research center dedicated to applied R&D. Over the decades of this center's existence, hundreds of students, especially in engineering, have benefitted from working on real projects of substantial significance to business or the military. Federal policy that strongly encourages this link between education and applied R&D can both enhance the student's education and produce greater economic competitiveness. At the same time, the ongoing interaction between university researchers, business or government agencies creates an intimate knowledge of the emerging needs of that industry. From our experience, this has produced tremendous results to date. As NSF data have shown, in the area of industry-funded R&D in aviation-related fields, WSU is top in the nation by an order of magnitude.

- Basic science research is critical for the long-term health of the American economy and increasingly federal support for basic research has been concentrated in relatively few dominant research universities. Federal policy does not focus at the doctoral level in terms of support for applied R&D that can be impactful in the short and medium run in creating and sustaining economic competitiveness of many American regions. Perhaps it is time for "Bayh-Dole 2.0" that incentivizes strong STEM doctoral programs that are based in applied R&D partnerships with businesses.

  Business has incentives to invest in universities that have strong applied R&D programs in STEM, but the universities themselves have had few such incentives. Focused doctoral student funding for STEM doctoral programs that focus on applied R&D could be of great, immediate assistance. It might be possible, for example, for a federal policy to make these funds available only to institutions that document support for such funding by STEM enterprises and could promote immediate application and increase the future supply of faculty who value, and are trained in, how to effectively conduct applied R&D within a university context.

- It is always difficult to make broad policies that affect hundreds of millions of people, and there is a tendency to "rifle shot" policy. In the case of STEM education, recognizing in policy the importance of how the ecosystem within which the education occurs would be of great benefit.

There is a great deal of literature on why students go to college and how they choose programs and majors. If increasing the number of STEM graduates and the quality of their education are truly national goals, then recognition at the federal level of the importance of the broader ecosystem is crucial. This cannot be limited to education policy, but also involves economic development policy, urban development policy and most likely federal commerce policy.

- Given the federal role in "accrediting the accreditors," encouraging regional and disciplinary accreditors to create and implement policies encouraging innovation, experimentation and entrepreneurship in developing new delivery systems, new modes of education and stronger relationships between outside constituencies and universities would be of substantial benefit. Accreditors play a critical role in quality assurance, but the impact unintentionally reinforces the status quo. Given the changes required of higher education to meet critical national need for STEM educated individuals, different approaches to accreditation that support experimentation are crucial.

  No one is suggesting that accreditation should be eliminated or that it does not focus on quality. At the same time, it tends to be a conservative approach that reinforces the status quo definition of quality. Outcomes-based accreditation, rather than more input-based processes that are currently still the norm, can promote experimentation, innovation or entrepreneurial actions by universities and professions.

- Federal financial aid currently is focused on traditional degrees taken by full-time undergraduate students, yet all indications are that non-degree short courses, certificates, stacked credentials, and mixed traditional and apprenticeship programs offer great opportunity to expand the number and capacities of STEM-qualified students. Not reaching out and supporting students with great financial need (both traditional and older students) greatly reduces both the supply of STEM-qualified individuals and limits the abilities of the regions to expand STEM-based businesses. There should be much better alignment between the federal financial aid system and the rapidly changing environment in which we all are working.

  According to news reports, this issue is under consideration by the Senate with regard to re-approval of the Higher Education Act, and it represents a critical opportunity for Congress to make clear its intentions with regard to the changing nature of academic programs that support STEM and other forms of education.

- Federal data-reporting requirements, especially through IPEDS, are woefully separated from the emerging realities of new forms of tertiary education. Because of how IPEDS is utilized within higher education, this is a major limitation that reduces experimentation and innovation. The focus of IPEDS simply no longer represents our reality in higher education and tends to lead both university leadership and various external policymakers to focus on very limited outcomes measures. Rethinking IPEDS and other federal data reporting systems to align them with the new approaches to education will be a clear signal to institutions of national priorities regarding implementation of new definitions of completion and performance.

- Currently, federal policy does little to encourage institutions to partner with external entities, and within the academy these partnerships often are derided as "corporatization of the university." There is very little recognition within the academy or in federal policy that traditional organizational structures that supported the industrial economy are counterproductive in the post-industrial, technology-driven economy. Refocusing the missions of research universities to allow unique differentiation of the type of teaching, research and service they provide would be beneficial. Other countries with which we compete have already addressed this issue; for example, the development in the UK of "business facing universities." The U.S. is very late to the table. Given the internal culture within much of higher education, policies that boost these external linkages can be of great benefit in encouraging institutional transitions to new models of education that promote quality within the highly technological, globally competitive world within which we now all operate.

  In sum, it is time for Congress to consider Bayh-Dole 2.0. You can affect the competitiveness of our communities regardless of whether they are on the coasts or in the national heartland. Your actions today, in this and the next session of Congress, can mark the re-emergence of American competitiveness and drive the quality of life for future generations of Americans across the states.

Again, thank you for the opportunity to share with you what we are doing at Wichita State University, and I would be happy to respond to any questions.

President John W. Bardo

John W. Bardo was appointed president of Wichita State University in 2012 by the Kansas Board of Regents. He has dedicated his administration to building a student-centered, innovation-driven modern university that will be an ally with residents, entrepreneurs, industry and government in growing the local and state economy.

He has articulated a vision that is also an invitation to students, faculty, staff, alumni and community members: "Envision being part of a university where innovation, creativity, entrepreneurship and technology are making the future. That is Wichita State University."

Wichita State's Innovation Campus and applied learning initiatives have drawn positive national attention because of the partnerships forged with local and international companies including Airbus, Dassault Systems and Koch Industries. The university has a long history of working with industry through its National Institute of Aviation Research and National Center for Aviation Training.

Prior to returning to Wichita State, President Bardo served 16 years as chancellor at Western Carolina University and held previous leadership appointments at Southwest Texas State University, the University of North Florida and Bridgewater (MA.) State College.

He grew up in Cincinnati, Ohio received a bachelor's degree in economics from the University of Cincinnati. He earned a master's degree in sociology from Ohio University and a Ph.D. in sociology from Ohio State University. He also attended the Institute for Educational Management at Harvard in 1987.

His first academic appointment was at Wichita State as an assistant professor of sociology. He also worked and taught in the Hugo Wall Center for Urban studies. During his time at Wichita State, he also obtained a Fulbright to Australia where he and his wife, Deborah, studied Americans as migrants and he had a sabbatical appointment at the University of Wales at Swansea in social policy.

His academic interests involve the relationships between higher education, the economy, and quality of life. He speaks regularly on issues associated with the New Economy and building competitiveness. When he is not working, he enjoys international travel and working with stained glass.

For more information, contact president@wichita.edu

Chairwoman COMSTOCK. Thank you very much. I really appreciate all this testimony. It's given us so much food for thought, as well as great visualizations, too. So thank you.

You know, as I was watching the video and as I go around and talk to businesses, as well as our schools, we know it's always a challenge to get more young women involved and engaged and stay in, as well as underserved populations and minorities, so I think a lot of what you've talked about here really addresses some of that, too. So how can we really, maybe, get them like from kindergarten?

I know in my district we have a children's science museum that is stood up and now is going to expand and that's where my three-year-old granddaughter loves to spend every waking moment. And I've been in kindergarten classes now where they're coding and—you know, there's no daylight and everybody's in there. And what some of our schools that have like the highest—very high-needs schools, high—school lunch programs, have some of the best science programs in it now. So how do we get that pipeline way down there so that there's never—you know, they're always in it? I'll start with you, Mr. King, sure.

Mr. KING. And that's focusing more on the interest, right, to keep them——

Chairwoman COMSTOCK. Yes. Yes.

Mr. KING. Yes. I'm a big stickler on putting together achievements as, you know, Dr. Bardo had mentioned, having those achievements all the way through from that young age going through their career. And I want to put a personal—just a personal question—attribute here is that I was—someone showed me how to chase a thread. I needed a bolt for my bicycle, and it stuck in my head. And that was it. I was done. The rest of my career I knew exactly what I wanted to do. I wanted to be—I changed everything about my perception of college and how I would go through. And I think those types of experiences and moments is what we need to share with the kids so that they can do an interest inventory at that early age, and with that interest inventory it leads you out to your career. And it's a true career, not something that's being pressured by what others say. It's about what you actually enjoy doing.

Chairwoman COMSTOCK. So it's with those young children, instead of maybe Daddy comes in and does something for the little girl, that they actually walk them through it——

Mr. KING. Yes.

Chairwoman COMSTOCK. —and say you can do it, too.

Mr. KING. Absolutely, but then you have those underserved communities where they don't have that father——

Chairwoman COMSTOCK. Yes.

Mr. KING. —or they don't have that mother to show them, and that's where mentoring becomes an important piece. And so that's why I've dedicated over ten years of my life mentoring individuals that have that gap so that they can get the same experience. It's just not through their biological.

Chairwoman COMSTOCK. Right. And Dr. Bardo?

Dr. BARDO. If I might, please. One of the things that we know is that we lose a lot of girls in middle school, and so really encouraging college women to spend time with girls in middle school is

a big deal because it gives them a role model. It shows them you can be a normal girl and major in a STEM area. If you look, many of the new areas, particularly in engineering, are becoming more female-centered. Bioengineering we're seeing a lot more women interested. And part of the sales there is you can make a difference in people's lives, and so it becomes, you know, yes, it's math, yes, it's engineering, but at the end of the day, I can make a difference in people's lives.

The other thing that we're experimenting with are half-credit-hour badges. We know that mother of three who's trying to hold down two jobs isn't likely to be able to make a 15-week course, so what we've done is break down many of our areas into half-credits that take about a week-and-a-half to do, and you can probably figure out how to get a babysitter or how to make things work and that allows you to inch in. So we're pretty excited about that.

Chairwoman COMSTOCK. Oh, that is great. And then also with—you know, I have a young woman's leadership program, and one of the things we try and do with the young people is get them into a workplace setting. You know, my mom was a teacher, my dad was an engineer but he was sales, so I never was in those type of job settings. I wasn't in a hospital, I wasn't in a manufacturing plant, and a lot of these places where you just don't understand what goes on there.

So I think what I love about the mentoring programs and doing this is you're really getting kids in there and making sure we can get them to get some experience and see themselves in a workplace and see the whole path around them and the kind of environment they would be in. And I would think, particularly with an underserved population that might not have that experience where mom or dad is taking them to a workplace, that, you know, this really seems like a great way that we can get everybody on a level playing field where we get them engaged. And I guess that's sort of not quite as a question, but, Dr. McCrary——

Dr. MCCRARY. Well——

Chairwoman COMSTOCK. —you have a——

Dr. MCCRARY. Yes, Chairwoman Comstock. One other way that we've been able to successfully do that is engage the technical professional societies who have engaged with students at a very early age. So, for example, we worked in a program a few years ago with the American Chemical Society, the National Organization for Professional Advancement of Black Chemists and Chemical Engineers, and parents very early on. What happens when your young daughter says I'm going interested in becoming a chemist or becoming a chemical engineer, and so get those societies working very early, particularly the minority technical societies like Society of Hispanic Engineers, SHPE, Society of Women Engineers.

Many of these national organizations have chapters throughout the country that are working at the K–12 level and at the same time offering workspace opportunities, as you mentioned, bringing people in chemical plants and engineering places and exposing them to them—students to them. So those type of programs are strongly encouraged.

Chairwoman COMSTOCK. Great. Okay. And I will now recognize Ms. Bonamici for five minutes.

Ms. BONAMICI. Thank you, Chairwoman Comstock and Ranking Member Lipinski, and thank you to all of our witnesses.

First, I want to express concern about President Trump's proposed budget plan. He's calling for a large cut to the Job Corps program and as well as completely eliminating funding for WANTO, the Women in Apprenticeship and Nontraditional Occupations. We have in Oregon, Oregon Tradeswomen, and they receive funding through WANTO. They've been recruiting, preparing, placing, and retaining women in the building trades very successfully. We need to be investing in more, not less, in programs that prepare people to go to work.

And I frequently hear from employers out in Oregon about the challenges they face in recruiting skilled workers, and unfortunately, small and medium-sized businesses often don't have the resources to establish work-based learning programs. So I have introduced bipartisan legislation with my colleague also on the Education and Workforce Committee, Congressman Drew Ferguson from Georgia, the Bipartisan Partners Act, which would support partnerships to help small and medium-sized businesses establish work-based learning programs and support services for workers using existing funds so it's no additional cost to taxpayers.

Mr. King, I understand that the National Institute of Metalworking Skills helps manufacturing businesses of all sizes establish and implement apprenticeship programs, but can you identify some of the challenges that small and medium-sized businesses face creating those job-training programs and how Congress could help level the playing field? And I do want to save time for another question as well.

Mr. KING. When it comes to the smaller organizations, even bigger organizations dealing with the unions, for manufacturing-sector jobs, the registered apprenticeship program has proven to be a little cumbersome and not as attractive for many of the employers. You can go into the construction industry, and it's working well for them, but when you're thinking about manufacturing, it does pose some problems. And the ROI, return on investment, it doesn't seem attractive to employers.

So as a member of the task force, we are working towards recognizing apprenticeship programs because there's many programs out there that we call pseudo-programs. I mean they're training. Most companies are training; it's just not either registered or it's not recognized. And with a few quality checks to make sure that it includes some of the key components, I think we can expand more work-and-learn opportunities, and we can of course also spark more interest in kids.

Ms. BONAMICI. Terrific. And I encourage my colleagues on this committee to look at the Partners Act that Congressman Ferguson and I have.

I want to shift a little bit to big picture, and I know the Chairwoman and Ranking Member know that I'm on the Education and Workforce Committee, as I mentioned, and have over the years looked for ways to make sure that students who are going through school who may be interested in STEM are educated to be more creative and innovative because I keep hearing about the innovative economy. So I started the STEAM Caucus and—about inte-

grating the arts and design into STEM learning, and there are nationally recognized STEAM schools across the country that are very successful in engaging more students in STEM learning.

CTE, career and technical education, as well in the K–12 system, the more well-rounded education that is part of the Every Student Succeeds Act which this—the last Congress passed with strong bipartisan support is also going to help engage students early on.

But what I wanted to mention is that not too long ago Google decided to test its sort of hiring hypothesis and they crunched all the numbers—hiring, firing, promotion data—since its inception. Here's what they found. Of the eight most important qualities of their top employees, STEM expertise came in last. The seven top characteristics were all soft skills: being a good coach, communicating, listening well, possessing insights into others, including others of different values and points of view, having empathy toward and being supportive of one's colleagues, being a good critical thinker and problem solver, and being able to make connections across complex ideas.

So I know that we're talking about blue-collar STEM jobs here today. However, for people who want to advance in careers and for people who want to be successful and stay at companies, what are apprenticeship and work-based skills training doing to include all of these really critical interpersonal skills in their curriculum? I'll start with Mr. King and then anyone else who wants to weigh in.

Mr. KING. Sure. With the work-and-learn apprenticeship models, it gives you those soft skills by—I can tell you, for example, for me coming into my—on a work-study program, the work day started at 7:00, and I got there at like 6:50 and it was about five minutes after 7:00 when it was time to work. I was a good kid, but I just didn't have the soft skills. But the work-study program and working around those professionals is what helped me develop the soft skills I needed prior to even—I mean, you could've taught me all you wanted in the classroom. It was in that workplace is where it actually happened for me.

Ms. BONAMICI. Does anyone else want to add to the importance of the soft skills?

Dr. SANDS. Yes, I'll add a little bit to it. You know, as I mentioned, we work with several companies in their—in the design of their apprenticeship programs, and part of what we try to do is ensure that the types of tasks and jobs that students are involved with will help build those types of skills.

And we've worked with—you know, there's programs out there—I don't know if you've heard of Necessary Skills Now through the Center of Occupation Research and Development, but they focus on six areas. And part of what I think needs to be done is those types of things like communications and ethics and so on need to be built into the experience of an apprenticeship program. It's not just the technical aspects but it's also, like you said, the workforce skills.

Ms. BONAMICI. Thank you. Dr. McCrary?

Dr. MCCRARY. I just wanted to give you an example. Morgan State University is a member of a—has a Center of Academic Excellence and Cybersecurity, as one of our colleagues mentioned earlier, and when we met with them last fall, not only did they want to meet with our Dean of Engineering and our Dean of Computer

Science, which is natural, but also our College of Liberal Arts and our School of Business. Why is that important? Because cybersecurity is not just confined to electrical engineering and computer science. It involves psychology; it involves foreign languages. And so they wanted to have that approach in terms of their research. And so for students in those areas, they also want to attract those students, as well as those in the hard-core STEM areas.

Ms. BONAMICI. Absolutely. Thank you very much, and I yield back. Thank you, Madam Chair.

Chairwoman COMSTOCK. Thank you. And I now recognize Mr. Marshall for five minutes.

Mr. MARSHALL. Yes, thank you, Chairwoman.

Dr. Bardo, when I think of Wichita State University, I think of the innovation creativity entrepreneurship capital of the world. And you guys have always been way out there. You've always been a great visionary. Can you just take a minute and share a little bit about your Innovation Campus and what that looks like just so the other members could hear it?

Dr. BARDO. Sure. What we're attempting to do at Wichita State is actually create an innovation university. And when you do that, you have to start with something that people can recognize. So we started by taking an old golf course and turning it into a public-private partnership enterprise where students can work. They can take three and four years of work in real businesses working on real projects at the same time they're studying general education, studying liberal arts, studying engineering, biology, whatever area they're in. We're making it a living learning environment because what we know about innovation is it isn't something that happens from 8:00 to 5:00. It could happen at 3:00 in the morning. It could happen over a beer.

And so we're encouraging restaurants, hotels, other entities that encourage students and faculty to come together and collide with each other and with businesses to be on the campus. We've seen a major increase in business interests. We have drawn businesses from as far away as Sweden to our campus. And, you know, we're in the great flyover. We're right in the center of the center and it can be done in that area, and it can be done successfully. But we're seeing great interest to a point where tours are getting to be a little bit of a problem because we're giving so many of them, and we're seeing excitement both in the local community and in the broader technology industry around us.

Mr. MARSHALL. So your largest employer there I assume is Koch Industries. What have they done on campus with you guys?

Dr. BARDO. They've done business on our campus in terms of creating a business center. Annie Koch, who is Koch's daughter-in-law now is creating an experimental school to see if we can take young children and get them engaged in STEM issues and in innovation early so—they're starting with preschool actually. And their building this school right on the campus, right near Airbus, right near our engineering building, and we're encouraging those students to be engaged with us from the time they're little children. We think that that's a way of getting them excited, getting them interested and then over time, as we learn, we'll try to generalize this out into public education but we'll also start encouraging students with dis-

abilities, low-income students also to come in and be part of this experience so that it's a different way of looking at education as well.

Mr. MARSHALL. Talk about teach the teachers a little bit. One of my biggest concerns is that this needs to be introduced in grade school much like used to teach French in grade school. I know Emporia State back home is doing a great job with teaching the teachers. Are any of you having experience with—how are we teaching the teachers, Dr. Sands?

Dr. SANDS. Yes, I'd like to maybe highlight one of the programs that's funded through the National Science Foundation. We run a cybersecurity center at Moraine Valley, and a big part of the cybersecurity center is a faculty development academy. And over the years it's evolved so, first of all, it's a virtual academy. Most computer systems nowadays are accessed remotely, so this academy is actually accessed remotely. And we're able to train faculty from across the country at free or very low rate. And basically, especially in the area of cybersecurity, is that the target moves constantly and the content changes constantly, so faculty development is a critical part of running quality programs. So we've been able to train—over the ten years that we've run the academy we've trained over 6,000 faculty members from across the country, and that would include high school faculty, it would include community college, and we've even had university faculty be part of it. But centralizing those things and having national centers like the ATE centers enables, you know, less—a better investment and able to reach a larger audience without having to have centers all over the place.

Mr. MARSHALL. I have time for one more question. Dr. Bardo, talk about the—is it the *Bayh-Dole Act*? So paint the picture. What would that look like in the future? If you were king, paint that picture what Congress—what it needs to do—be done to update it for us.

Dr. BARDO. Well, we have—I'm not sure exactly what you're speaking to.

Mr. MARSHALL. The *Bayh-Dole Act* you talked about——

Dr. BARDO. Oh, the *Bayh-Dole Act*, yes.

Mr. MARSHALL. Forgive me.

Dr. BARDO. Birch Bayh was a well-known Congressman many years ago, and of course Senator Dole we all know and love. The *Bayh-Dole Act* allowed universities to take inventions and to sell them to the marketplace. Prior to that time, the Federal Government owned anything that the Federal Government participated in. This was a sea change for universities, and we didn't recognize it.

What the *Bayh-Dole Act* II would do—I mean, it obviously would have a different name and it might be the Comstock-Marshall Act but the—

Mr. MARSHALL. It has a ring to it.

Dr. BARDO. But the—what this would do would be to focus on what does the next generation need to look like? So, for example, to solve the problems of cybersecurity, to solve problems of health takes big science and big data. And what's ended up happening is that a relatively few universities control basic research, which isn't necessarily a bad thing. Don't—I'm not criticizing. But for the rest

of us we can make a real impact by integrating the work we do with the community.

And so the *Bayh-Dole Act* II would really focus not on transferring intellectual property to business but would focus on trying to create applied STEM work that would benefit faculty, benefit students, and benefit the economy of the area. And in my long testimony I did make several suggestions of things that I felt might be something to be considered.

Mr. MARSHALL. Okay. Thank you. And I yield back.

Chairwoman COMSTOCK. Thank you. I now recognize Mr. Lipinski for five minutes.

Mr. LIPINSKI. Thank you. I want to thank the witnesses for their testimony. I want to start out by asking Dr. Sands about—sort of elaborate on the cybersecurity credential, how you would see this coming about, how does that get—how would that get established in your eyes?

Dr. SANDS. You know, we have several national programs out there now that really could be leveraged to build a national credential. So, you know, as an example, the NSA/DHS Centers for Academic Excellence, they've established credentials for institutions so, you know, as far as aligning curriculum, faculty requirements, even institutional requirements. You know, if you're hanging a sign out at your institution at your cybersecurity center, guess what, you've just become a target, so you need to practice what you preach.

And so part of that program has set those types of standards, and I think it would be an ideal program to expand those types of things to student credentials that as soon a student could earn as part of their service in an apprenticeship program. And a really good example of that might be the SFS program. So the SFS program, now the CyberCorps program, it's a scholarship program where students basically are awarded a—funding for scholarships during their academic time at school, and then they have to pay that back through service to either a federal agency or state or local government.

But I think we could actually put standards on that apprenticeship program, and they could earn those credentials as part of their service in the apprenticeship program. Right now, there really isn't a standard out there for that.

And the other thing I think would be really important is that the SFS program really focuses on federal and local government jobs. I think that should be expanded to the private sector as well because the private sector is suffering right now with the shortage of cybersecurity workers as well.

Mr. LIPINSKI. Now, do you find—is it difficult to find students who are equipped to enter the—you know, the CyberCorps Scholarship for Service program?

Dr. SANDS. I think there's a challenge, and it's a very selective program. But I think as more and more community colleges—community colleges are new to the game, so they just came into this program in the last two years, and I think community colleges will have a lot in contributing additional students into the program.

But I think other programs like GenCyber, it's a program that's funded through National Science Foundation also, enables us to run summer camps. So like this summer we ran a camp—a

GenCyber camp, and we had 50 kids. By the way, half of them were women, which is really unusual in this area—or young girls. It even reached out to organizations like the Girl Scouts. But it allowed kids to come in for a week and learn everything from basic coding, capture-the-flag types of activities in cybersecurity, and then it wrapped up with a short competition.

But what it enables us to do is to get the really talented kids that never thought about this type of career or a career in the STEM area to see the types of jobs that are out there and then the types of skills and opportunities that are provided in these fields.

Mr. LIPINSKI. And I know that you have developed curricula for grade school, high school. How do you go about doing that? Do—and do you see schools being, you know, willing and able to, you know, implement these?

Dr. SANDS. It was a challenge early on because most schools don't want their students using cybersecurity tools on their production networks, so what we found was a model that, again, uses a virtual environment. So most schools aren't going to let students even modify credentials on their local machines. But by creating a curriculum that's virtual, now you have a safe sandbox where kids can actually learn the administration of systems and they can actually use systems that take advantage of vulnerabilities and see how those things work.

And the other thing with that is that we can actually control what we are exposing students to, so, you know, we want them to see the benefit of these tools, but we also want, you know, there to be ethics that's taught as part of the program and so on.

But I think, you know, just to address it, one other thing is, you know, exposing students to the actual jobs that are out there and then bringing them on trips to organizations or healthcare facilities or server farms where they can actually see what a typical IT or cybersecurity person does and the types of facilities that they work in. Most of us have no idea what those facilities look like, and, again, most high school teachers have never experienced those types of things.

Mr. LIPINSKI. Thank you. And I want to thank you for your work and proud to have you in Moraine Valley there in the southwestern suburb of Chicago.

Dr. SANDS. We thank you for your support.

Chairwoman COMSTOCK. Thank you. And I now recognize Mr. Banks for five minutes.

Mr. BANKS. Thank you, Madam Chair, and thanks for holding this important hearing.

I'm very pleased to see the Trump Administration putting an emphasis on expanding apprenticeships and expanding educational opportunities beyond the traditional four-year college degree as we've discussed today. There are millions of job openings in our country that require a technical certification short of a college degree. These jobs pay well and can support a middle-class lifestyle.

And in my home State of Indiana, I was proud to work with then-Governor Mike Pence, who recognized the untapped potential in this area and instituted a number of initiatives to increase access to technical and career education. Fifty-eight percent of Hoosier jobs are classified as "middle-skilled," requiring more than a

high school diploma but less than a college degree. At the same time, only 47 percent of Hoosiers currently qualify as, "middle skilled."

According to the latest jobs report from the Bureau of Labor Statistics there are roughly 6 million job openings in our country. At the same time, the labor force participation rate among those 25 to 54 is still more than two percentage points below where it was at the beginning of 2008. We need to find a way to connect these workers with good-paying jobs that are and will become available which the data shows are often technical jobs that require certifications.

So my first question for you, Dr. Sands, as you direct an Advanced Technological Education Program, do you have protocols in place to enroll those who are currently unemployed to fill middle-skilled job openings in your area? Can you describe that?

Dr. SANDS. Yes. We have several different programs. I can highlight one program. We had a program last year where we worked with returning veterans, and basically, it was completely designed around short-term credentialing. So basically, we had a cohort of 12 veterans. By the way, 11 finish the program and 10 found employment after completing this program. But, you know, we have to change our traditional programs in many cases to reach those types of students. So they were able to finish this program in a 12-week period, again, work as a cohort.

It was almost the perfect program because a lot of these students that were veterans already had security clearances, which are really critical in the cybersecurity field, so we were really leveraging, you know, a national resource that was really sort of untapped. And we've run a second type of program since then that's also been very, very successful.

But I think in many cases what we need are programs that are based on stackable credentials, so there are many entrance and exit points, and curriculums that are designed around the requirements for those industry certifications. So not only are they gaining academic credentials, but they are—you know, like some of the other members have testified, they're also based around industry certifications and the skills and knowledge required with the industries.

Mr. BANKS. Great. Thank you. Mr. King, will your task force report on expanding apprenticeships include strategies on connecting prime-age workers that have dropped out of the labor force with apprenticeship programs and skilled technical positions?

Mr. KING. Yes, that is a major goal within expanding apprenticeship is not just for, you know, feeder system out of schools but even those—I have a statistic here that shows that there are about 5.5 million disconnected people between the ages of 16 and 24 who are currently out of school and not working, and so the key is to—you know, how do we get those individuals involved and teaching them more about the truth and reality of the opportunities and also including industry-recognized credentials where you can attain those credentials without having to go through a four-year program or even a two-year program. And as you earn the credentials, you can then articulate those into college pathways if your heart desires. So yes, with the industry-recognized credentials, it makes attaining

these jobs much more accessible to these individuals that you're speaking of, yes.

Mr. BANKS. Thank you very much. Thanks for being here. I yield back.

Mr. MARSHALL. [Presiding] The Chair recognizes Ms. Rosen for five minutes.

Ms. ROSEN. Thank you. I want to thank you all for being here today. And I know Chairwoman Comstock isn't here, but I want to thank her because, this week, a bill that I originated, Building Blocks of STEM and Code Like a Girl Act, were actually passed out of this committee and voted on unanimously in the House Tuesday night. And so, as a woman who's a former computer programmer, I am especially interested in young girls learning to code, and the Building Blocks of STEM does what you guys are doing, helping teachers in the classroom with curriculum and training and scholarships and education. So I thank this subcommittee for moving that forward and then the whole House and everyone who worked with me on that because we got something done this week in this space.

So I want to talk a little bit about community colleges, local businesses, how we create those public-private partnerships. You know, when I'm in Nevada, I ask my local businesses, just like you said, to show kids a pathway to work for them for a good job in their company, whatever that is, whether it's in elementary school, junior high, or high school and to engage with those kids, Boys and Girls Clubs, wherever it makes sense for their business because we know—I know that the fear of data and analytics, it's really that fear I'm not smart enough to analyze this or see a computer or think about data is the barrier to success.

And I had the opportunity to participate in some STEM roundtables with colleges—kids at the—or students at the College of Southern Nevada and community college, and we know that we're not funded so well there. So I guess I want to ask all the panelists. What can we do through the—if it's not NSF maybe through the Department of Education or the Department of Labor to reach out with our community partners like you're doing in a broader way to overcome this fear of data and analytics and show people a pathway to these kinds of jobs. You know, if you watch TV, you think there's about three jobs, police, firemen, right, and so they're not getting exposed to some of these really interesting, amazing jobs. So could you speak to some of that?

Dr. MCCRARY. Briefly. I think a couple things that we have to do is start also at the K–12 level and start with both parents and counselors. Particularly for the skilled technical workforce, we have to remove the stigma about these jobs, that these are actually good-paying jobs, as well as showing multi-ramps or onramps toward careers.

As one of my colleagues says, it's not just going to four-year schools or bust but also there are a lot of other opportunities in those jobs. So I think one is working with high school counselors, working with parents. I will say that's—what I said earlier in—some of the technical organizations have held trials working with parents, talking with parents who may be—their students may be first-generation college, so talking to them about these careers.

I think the other thing is building partnerships, and so that's where the National Science Board and NSF can facilitate that conversation between community colleges, technical schools, four-year schools and even trade union organizations to talk about——

Ms. ROSEN. Right.

Dr. MCCRARY. —the opportunities that are there and the ability for people to manage their careers throughout the spectrum.

Ms. ROSEN. Fantastic. Anyone else want to address it?

Dr. BARDO. Please. We are in the process of amalgamating a technical college within a research university, but we also are in the process of restructuring our College of Education to be the primary face that works with the technical college because we really do believe that there's a combination there of working with the teachers, working with the schools, and starting young. But the technical college in Kansas has the authority and the funding to work in the schools——

Ms. ROSEN. Right.

Dr. BARDO. —which we as a research university don't. At the same time, we've got capacity to prepare the teachers for the changes that are coming.

Ms. ROSEN. Right. I think that's where it starts, with the teachers in the classroom.

Dr. BARDO. Right. But we've been very excited because one of the projects—aircraft is designed throughout the world with the software package called CATIA and working with CATIA—actually with their parent company—we've been able to get that software into the schools for free. And so when a student comes to the university, they've already been programming in the core language that is being used in industry.

Ms. ROSEN. Fantastic, thank you. I really appreciate all the work you're doing. It's so important and empowering our teachers to realize that there's pathways for kids to learn these skills and all kinds of great ways is the best way to do it, so thank you. I yield back my time.

Chairwoman COMSTOCK. Great. And I now recognize Mr. Tonko for five minutes.

Mr. TONKO. Thank you, Madam Chair. And welcome to our guests. I would hope just listening to some discussion, that while we advance this effort for skills-based programs, we need to keep that balance going with higher ed so that we don't abandon one against another. They're both vitally important. So that concern is one that I think needs to be addressed head-on.

I recently met with leaders at Hudson Valley Community College, HVCC, in my capital district region of New York, an institution that is making a difference on the issue of workforce needs and in advanced manufacturing. They shared insights from local business leaders and employers expressing the need to train more people in advanced manufacturing in order to close the skills gap both in our region and certainly in our country.

By 2024 the—New York State will have an estimated 168,730 new jobs open in advanced manufacturing and many more obviously across the country. With an aging workforce and rising demand for the skills, we need to be preparing our students, our schools, and our industries now to ensure we have workers ready

to enter these emerging fields. HVCC is taking a visionary step forward in this space, creating the Gene F. Haas for Center for Advanced Manufacturing Skills known as CAMS, which will allow the college to double its enrollment in the advanced manufacturing technology, their AOS degree program, and meet the urgent and growing demand for skilled workers in our region.

CAMS will be a one-stop hub for employee training and recruitment. The building's design provides corporate partners with access to offices and conference space adjacent to faculty offices, student classrooms, and labs. Facilities will be available for business demonstration purposes, shared training activities, meetings, and events that connect the college to its workforce partners more than ever before.

HVCC is also developing innovative programs for student workforce training. For example, their Manufacturing Technology Pathways program allows students to take short noncredit skills—skills-based courses leading to local certifications that will help them develop a career ladder of stackable credentials for students that are valued by manufacturers.

They also offer an intensive boot camp training program providing a pathway to entry into careers in advanced manufacturing or the options of taking credit classes. I've also been told that, currently, there is more demand by employers for graduates of HVCC's advanced manufacturing technician program than there are graduates. It's a great thing to know we're training people for career opportunities that exist today. I've been at the graduations, I've seen the interest, I've seen the passion, and it's a powerful statement made by these young career-path-bound people.

Local companies such as Global Foundries, GE, Watervliet Arsenal, and Simmons Machine Tool Company compete to hire these graduates, and there is still a shortfall. This speaks highly to the program but also informs us of the urgency of closing this skills gap.

So to all panelists, can community colleges fill a vital role in the community of closing skills gaps? Is there a special relationship that they can have with—that closes the gap between industry and higher ed? Anyone?

Dr. MCCRARY. Well, you—one of the things that you pointed out, the balance between the skilled technical workforce, apprenticeships, and also higher education, if you think about in the STEM fields, 49 percent of those people who entered the STEM fields come through community colleges, and so community colleges provide those opening doors and a path whether you want to go on for a four-year education or go in for, say, a higher technical skilled workforce degree.

I think in those areas that's where the community colleges can really link with the four-year institutions, as well as with the trade organizations to be those pathways for those skilled technical workers and to be able to fill the shortages.

Mr. TONKO. Dr. Sands?

Dr. SANDS. Yes, I'd like to also speak to this. I think community colleges play a special role in that, so community colleges can provide a second chance so, you know, someone didn't—you know, failed a chance to go on to a university many times come back

through the community colleges, get credentials, get in the workforce, and many of those students go on to finish undergraduate and graduate degrees. But we also get returning—we've had in our program people to return with graduate degrees, they come back and they are either changing careers or they're trying to upgrade their skills. So I think community colleges are well-placed to provide those types of options.

And, you know, when I go to different things within my community, I mean, whether it's at a hospital or an auto repair place or whatever, most of the times I asked where they're getting their students. And nine out of ten times, you know, I hear it's someone that came through, you know, the neighborhood community college. So I think, you know, they play a vital role in this.

Part of the thing is in investing so that they have the tools and the technology that represent the greatest impact and represent what industries actually need because I think that's the biggest challenge we have sometimes is that, you know, a lot of these things are changing at a rapid pace and community colleges don't always necessarily have the funding to represent those types of technologies and the types of skills that are necessary to meet changing areas of technology.

Mr. TONKO. Yes. Dr. Bardo, were you going to say something?

Dr. BARDO. Yes—

Mr. TONKO. Mr. King, too?

Dr. BARDO. Yes, just very quickly. One of the really big issues that we are seeing is we do so much applied research that we're seeing five and ten years out what the advanced manufacturing is going to look like, and it's going to be very different than it is today. We're working with major corporations primarily from the Midwest but really all over the world, and the changes that are coming are dramatic. So it's not just the funding for today and it's not just getting them into the job today. One of the issues we're seeing in Wichita is people aren't silly. They look and say, "Well, wait a minute, in five years, we're not to be making aircraft the way were making them today. We're not going to be designing fuselages the way we're doing today, so why should I spend all that time preparing when I know that my job's going to be gone?"

So having a long-term view where you give people a ladder to success so that it's not just today's job, but if you take today's job, we're going to continue working with you and help you move as advanced manufacturing moves.

Mr. TONKO. Thank you.

Mr. KING. Yes. I think community colleges are extremely important. Right now, NIMS, we're working with Raytheon, which is a large missile defense company with an apprenticeship program that we're planning to scale across the entire organization. And—but we're working in Tucson first as a launch and we're actually—we brought—we're bringing the college and Raytheon together with NIMS as a consulting piece to work together. So Raytheon and the local college, they're now going all the way—they're planning to go all the way into the middle schools to start giving Raytheon hats. I mean, you know, and the community college will be working with them on the recruiting piece. So it can't be done with just one

piece. It has to be done together. But putting skin in the game, we have Raytheon and the college working together. I think that's key.

Mr. TONKO. Thank you. I yield back and I thank the Chair for allowing me to go well past, but we had a lot of people anxious to answer, so——

Chairwoman COMSTOCK. Yes.

Mr. TONKO. —thank you, Madam Chair.

Chairwoman COMSTOCK. No—and I appreciated the information, too, so thank you.

And I now recognize Mr. Hultgren for five minutes.

Mr. HULTGREN. Thank you, Chairwoman. I appreciate you all being here. This is a very important hearing and it's something that I'm passionate about.

As a Member of this Committee, I see sparking an interest in young people in STEM fields as a vital part of what we need to be doing and certainly what our nation needs in order to remain competitive going into the future. More importantly than that, I do think discovery and innovation are part of our DNA as a nation.

Back in my district I've had the privilege of starting a STEM scholars program where I meet with about 30 young people, high-schoolers from around my district. I represent seven counties just outside of Chicago, and this is our second year of having our STEM scholars. And I meet with them once a month. I'm going to be with them this Saturday for a couple of hours. We go to different parts around northern Illinois to see how they can apply STEM education and STEM passion in careers right in our area.

We're so fortunate to have some great laboratories like Fermilab and Argonne, but we have some amazing companies that are doing some really cool work as well. And every place I go people are looking to hire more engineers, more programmers, so we need to keep figuring out ways to spark that.

I asked them if they had any questions for you all. I hope it's all right. I'm going to throw out some questions from my STEM scholars and see what your thoughts are. One of the scholars, Akin from Oswego, stressed the importance of hands-on learning and the effects that internships for high school students can have. These are often hard to find and take a company that is willing to host. His school can also give credits for these internships. How can we measure the success of this kind of career exposure at a younger age, and how can we improve the relationship between businesses and schools to develop these opportunities?

Dr. MCCRARY. I'll give you one example, and this is at the four-year level because there's a concern even at the four-year level that many of our students, even our engineering students are very good from a book point of view but they don't know the difference between a Phillips head screwdriver and a regular screwdriver.

Mr. HULTGREN. I struggle with that, too, but——

Dr. MCCRARY. One program is we're working with industry is we're working with Northrop Grumman. Morgan State University is located in the Baltimore/Washington region. Part of that industry is national security. They have a program called cyber warriors, and what they have done is they're working with our students. They have them do hands-on coding. Actually do mock attacks on systems and—so that our students can get that hands-on, plus cou-

pled with internships. You know, when I came along—I won't say how long ago—you could come out and not have an internship during the summer, you'd go work for a company, and they'd say you can get up to speed in two years. But most businesses nowadays are out of business in two years if they can't have an employee who hits the ground running.

And so also with many of our companies, as well as government partners like the Navy, we work very early on, freshman coming in and getting internships and getting hands-on experience, coupled with their formal learning makes a product that comes out the door that both industry and government wants.

Mr. HULTGREN. That's great. One of my STEM scholars from our first year was a high school student but was also part of a cyber warrior team through his high school where they were doing, like you said, these types of mock attacks but also learning from it. And I talk about it with my own kids. I've got four kids, but my younger guys are 13 and 16. Whenever they travel with me, they're my tech support team, so whenever I've got a problem or question with my technology, they're the ones to answer.

Let me get through another question quick. Another student, Taylor, who goes to school in Elgin, had some questions about your experiences as being mentors. How willing are you to take on a mentee, and how many are you able to work with? Have you turned anyone down? Also, how valuable are these experiences to you as a mentor?

I would throw it out maybe to one of the other panelists if anybody has a thought on being a mentor.

Dr. SANDS. You know, the way we sort of deal with that is that we have a couple different groups on campus that specifically serve as mentors.

Mr. HULTGREN. Right.

Dr. SANDS. So we have Women in Technology, and we basically have about 60 ex-graduates of the institution, and we pair them up with current students for mentorship, so it really expands our capacity. And we have that in several other areas.

And one of the other things I'd mention—you mentioned the national labs. We work with Argonne National Labs and, you know, they host an annual competition that students are able to get hands-on experience, but they have a group of businesses that work with the participants and provide mentorships and trips to their facilities—

Mr. HULTGREN. Great.

Dr. SANDS. —and—you know, and so on.

Mr. HULTGREN. Fantastic.

Dr. BARDO. The—one of the things we learn from the beta test that we completed is that the students are pretty excited about being involved in a real project in a real business.

Mr. HULTGREN. That's right.

Dr. BARDO. And what the business told us—actually, what the V.P. in charge of that division told us was that it gave a new life to many of the long-term employees, that they really felt that having the young person there changed their perspective as well. And so they had a reverse mentoring day every so often where the student would mentor the older worker as well.

Mr. HULTGREN. Great.

Dr. BARDO. And so mentoring within a formal organization, actually our experience has been that has been a tremendous boon both to the organization and to the student.

If I might mention, one of the things that we heard from industry is that if you hire a new engineer with a bachelor's degree it takes approximately two years for that engineer to contribute to your bottom line, which is why you'll hear industry say there are no engineers available.

Mr. HULTGREN. Right.

Dr. BARDO. Well, there are, but they're young ones——

Mr. HULTGREN. Right.

Dr. BARDO. —right? And so the—what we found is, as we put students through the apprenticeship program, that it cut the time to profitability for the business to six months, so it had a huge impact—

Mr. HULTGREN. That's great.

Dr. BARDO. —on the bottom line of the business. It had a huge impact on the workers who were working with the students, and it really changed the quality of the students' education.

Mr. HULTGREN. That's fantastic. I'm out of time. I have more questions from my STEM scholars. I may follow up in writing if that's all right to get answers to my STEM scholars. One last thing I'll say is quite a few of my STEM scholars are part of robotics. FIRST Robotics has been amazing. This idea of gracious professionalism, teaching young people, I think that's something we need to learn here in Congress about the idea of gracious professionalism, but so excited again about the mentor relationship that we see through robotics but so many other things and really encouraging, Dr. Bardo, to hear about how it is cutting down that time it takes for someone to add real value on the ground, so thank you. Thank you all for your work. I look forward to figuring out how we can work together as well for what we know is the right thing for America.

With that, thank you, Chairwoman. I yield back.

Chairwoman COMSTOCK. Thank you. And thank you, Dr. Bardo, for that point. That is really interesting and that really kind of goes to one of the things that we know in the future economy. You have to be lifelong learners. So for the mentors to also be getting that push from the mentees is exciting.

And I now yield five minutes to Mr. Beyer.

Mr. BEYER. Thank you, Madam Chair, very much. And thank you all for being here.

Dr. McCrary, in his recent report on America's skilled technical workforce the National Academies recommended that the National Science Foundation commission a study on how countries with, quote, "more proficient workers" have developed their skilled technical workforce. So we all know about the German experience with apprenticeships. So I lived in Switzerland for four years, and one of the most interesting pieces was that, you know, 70 percent of the kids were going into the technical vocational training rather than the college-bound. And they had the Fachhochschule, which is essentially their equivalent of the community colleges. And what's fascinating every year was that they—there were more jobs than

there were trained workers coming out of these apprenticeship programs. They're training people for the skills that were needed in the workforce.

So the key question that we asked overseas and which they tried to ask the Department of Labor through the Obama and early Trump Administrations was how do we change the culture here to make that happen?

Dr. MCCRARY. I think we have to change the culture is first we have to, again, as I said earlier, have to change the stigma. We have to say that very early on for a number of folks that there are opportunities besides just the traditional linear four-year track. Places like Maryland, places like South Carolina have started very successfully apprentice-based programs. And what they have done is they've gotten into the schools very, very early, talked to people about the different opportunities.

I'll give you a good example. In Baltimore city, right now, there's about anywhere between 1,500 to maybe 2,000 throughout the state electrical workers that—jobs need to be filled, according to IBEW about 100,000 across the Nation. But many of these jobs involve coding, and many of these jobs involve understanding circuit analysis. In some sense, the electrician that we knew years ago is not the same today. So what they have done is gone out to the schools and talked about how exciting these jobs can be, how they can put a number of things together.

And getting back to what you said about the apprentice-based education, one of the things our task force is going to be looking at is looking at that apprentice-based model and see how that compares with what we can do here, some of the programs that are going on in some of the states now, and how can we adapt parts of that to the economy here in the United States.

Mr. BEYER. Thank you very much. Dr. Sands, you have this community college background, which is terrific. You see more and more states little by little adopting the free community college model. It was led first I guess by a Republican Mayor in Memphis and then by a Republican Governor in Tennessee. I think the Republican Governor of Maryland is moving in that direction pretty quickly. Is this—by making that 13th and 14th grade free, does this help that? Do we still need to have a cash investment in it on behalf of the individual to make the education worthwhile? What's your perspective?

Dr. SANDS. I think it's more critical than ever. I mean, we look at the cost of universities and colleges across the country, and community colleges, even at the current rates, are really the only option that a lot of these students have. So, you know, any help that community colleges have in lowering tuition especially—I mean, I can just mention in the State of Illinois with our financial issues, the need for more affordable education is more important than ever.

Mr. BEYER. Very cool. And, Dr. Bardo, you talked about the mismatch in terms of where the apprenticeship programs have grown up. You know, we do great in Connecticut and in Virginia and maybe not so well in Louisiana and Arkansas. What's the long-term implication of having this disparity?

Dr. BARDO. I think the fundamental issue is that education changed a lot, and we in higher education have been slow to the table to get to the notion that you have to have experience and apply the knowledge that you learned to know—when I was in college, when you were in college, to pass a test, you know, you got an A, you were good. Then it became, okay, well, everybody has to have an internship, some kind of an experience. And what we're finding today is that really deep understanding of whatever you're studying, if it's English or it's engineering, really requires you to look beyond the classroom. And I think that not having that happening is really hurting our workforce, it's hurting our national competitiveness, and it's hurting the competitiveness of those states that aren't taking this seriously and moving forward.

Mr. BEYER. Great. Thank you very much.

Madam Chair, I yield back.

Chairwoman COMSTOCK. I thank the witnesses for their testimony and the Members for their questions, and now the record will remain open for two weeks for additional written comments and written questions from Members, including some of those that may be from the STEM scholars. That sounded very interesting.

And I really thank you for the good work you're doing. I think we are really going to be needing a sea change in how we approach these jobs, and you've really mapped out for us some ideal approaches on how we can really change this up for the better.

And the great thing about a lot of this is we're talking about people who aren't going to have to get hundreds of thousands of dollars in debt for going to college for a degree that may not even be what they wanted. You know, if we really start working with these kids at a young age, have them understand these jobs are available, really have them hands-on experience and see the whole career path and opportunities that are available to them, they can both get into areas that will, you know, pay for themselves, as well as really be what we need in the economy, so I just think there's a lot of exciting synergies here that we've just started to scratch the surface of, but you've really given us a great path here.

So I know we were already talking up here on some possible legislation in this area and how we can continue to support your efforts, so thank you for all you're doing. And we're adjourned.

[Whereupon, at 10:50 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Victor R. McCrary

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mentoring, Training, and Apprenticeships for STEM Education and Careers"

Dr. Victor R. McCrary, Vice Chancellor for Research, University of Tennessee, Knoxville; Member, National Science Board and Chair, Task Force on the Skilled Technical Workforce

Questions submitted by Ranking Member Daniel Lipinski, House Committee on Science, Space, and Technology

1. Existing regulations for apprenticeships require registered apprenticeship program sponsors to provide equal opportunity for participation and to protect their apprentices from discrimination. Despite these regulations, women and underrepresented minorities continue to face significant barriers to equitable participation in apprenticeship programs. Women make up about half of the labor force, but only seven percent of apprentices. Moreover, women and apprentices from minority groups tend to be concentrated in apprenticeships for lower-paying occupations. Why is it important that everyone have access to the full range of apprenticeship programs?

   Answer: As the National Science Board (NSB; Board) said in its 2018 policy statement,[1] to ensure that our Nation can compete in a globally competitive knowledge economy, we must ensure ***all segments*** of our population are "STEM-capable." Why? An increasing number of jobs require STEM-expertise. This includes the over 16 million "skilled technical jobs" that require technical expertise but do not necessarily require a four-year degree. Despite the need for these workers, employers in 80% of local areas said they had trouble filling jobs in occupations that depend on skilled technical workers. Simply put, our economy needs these workers, and expanding access to apprenticeships could help produce them. These jobs are well-paying and are located across the United States. Skilled technical jobs are located within most occupational categories, including fast-growing occupational categories within the information technology (IT) and health care sectors.

   But expanding access is also part of a broader conversation. One reason for this workforce mismatch is our Nation's persistent struggle to take advantage of the talents of all our people. Certain groups, especially women, certain racial/ethnic minorities, persons with disabilities, and military veterans continue to be underrepresented in STEM. For example, although women have earned about half of all science and engineering (S&E) bachelor's degrees since the late 1990s, the proportion awarded in high demand fields such as computer sciences (18%) and engineering (20%) remain low. Overall, while

[1] National Science Board (2018). "Our nation's future competitiveness relies on building a STEM-capable U.S. workforce – A policy companion statement to *Science and Engineering Indicators 2018*." (https://www.nsf.gov/nsb/sei/companion-brief/NSB-2018-7.pdf)

women occupy half of all jobs in the U.S. workforce, they constitute slightly less than 28% of workers in S&E occupations. These disparities are even greater at the PhD level and in leadership positions (e.g., tenure track faculty, federal laboratory leadership).

To remedy these disparities, educators, businesses, and Federal agencies like NSF must work together to provide women with additional on-ramps into STEM. These on-ramps could include apprenticeships, community college and technical school courses, certifications, and other similar initiatives. These on-ramps create multiple pathways into solid careers, such as those in high demand skilled technical fields, and also create paths to additional education and training opportunities. This ultimately leads to increased economic opportunity: licensed or certified workers in STEM occupations or with a STEM degree have higher earnings than other comparable workers, and STEM workers are less likely than others to experience unemployment.

a. What do you believe to be the major barriers to equitable participation in apprenticeship programs by women and minorities?

Answer: There are numerous studies and reports exploring the various barriers women and minorities encounter in their education/career pathways. I'll mention a couple. Young girls, beginning early in elementary school, are often steered away from STEM. For example, girls are sometimes taught—explicitly or inadvertently—the myth that women are not as proficient in math (or other technical subjects) compared to men. This even starts within some family structures of both mothers and fathers viewed by their children as STEM or STEM capable role models. There is evidence that minority students suffer from low expectations of teachers compared to other students, and they can feel excluded or unqualified compared to their peers. These often-unconscious biases are present at multiple levels of education and throughout the careers of women and underrepresented groups.

In the United States registered apprenticeships are associated with traditional blue-collar occupations such as installation, maintenance, and repair; construction, and production. These occupations skew heavily male. However, an increasing number of these jobs require skilled technical work skills rather than unskilled manual labor, and apprenticeships in the United States have grown and expanded into other sectors like IT and health care. Encouraging further expansion in "nontraditional" apprenticeships (and ensuring that women and underrepresented minorities are aware of these opportunities) will help address barriers to equitable participation.

At the same time, there is a persistent stigma that these education-training-career paths are second class compared to a four-year degree. As we have seen through

anecdotal evidence and surveys, the notion that 'college is for everyone' is just simply not true. This leads to many students saddled by debt and inflated expectations for a career trajectory that will not pan out. It is important that everyone not only have access, but understand the full spectrum of career apprenticeship choices. Apprenticeships and other on-ramps into STEM can open doors not only to well-paying jobs, but also unlock paths leading to additional education and training opportunities.

Lastly, as I alluded to above, individuals may not realize the options at their disposal. My experience has been that many women and underrepresented minorities are not aware of existing programs, either because their social networks (or their parents' networks) are inadequate, or lack of awareness of these programs on the part of high school counselors. Many underrepresented students attend schools which are resource-poor, and thus the counseling staff is limited.

b. How can apprenticeship sponsors and educational institutions improve their recruitment strategies to ensure equal opportunity?

Answer: Federal, state, and local policymakers, educators at all levels, businesses, and Federal agencies like NSF must work together to change persistent stigmas and biases associated with women and minorities in STEM. First, involving women and minorities in the development of recruitment strategies would lead to strategies that are cognizant of the different life experiences of these underrepresented groups. For example, during the NSB's recent listening session at Baton Rouge Community College, one recurring theme was that available education and training opportunities (e.g., research internships) frequently fail to take into account that these students have families and work at least one job to make ends meet. To take advantage of a short-term internship, many of these students would need to quit their jobs, devise a means of transportation, and locate adequate child care.

I would suggest that apprenticeship sponsors and educational institutions engage high schools—and in particular high school counselors—to discuss the benefits of apprenticeships. They should also work with the Minority Technical Organizations (MTOs). Many MTOs have local K-12 programs where they can demonstrate to kids the high paying jobs and exciting careers in these areas. These are organizations like Great Minds in STEM, the National Society of Black Engineers (NSBE), the Society of Women Engineers (SWE), the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS), and the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE).

Importantly, recruitment is just the first step. Studies show that women and underrepresented minorities "divert" out of STEM education and career paths at nearly every stage. The reasons are varied, but include disparities in pay and promotion, a hostile educational or work environment, lack of support structures (e.g., for women who wish to raise children), and lack of role models in leadership positions (e.g., paucity of successful minority professional mentors). Implementing at scale research-based methods aimed at understanding and overcoming explicit and implicit bias is vital so that once in an apprenticeship, women and minorities can progress and advance in their careers.

2. In its 2014 report entitled The Hidden STEM Economy, The Brookings Institution did a key word search on NSF grant recipients and found that "the vast majority of National Science Foundation spending ignores community colleges." What is your response to this finding?

Answer: NSF does not ignore community college or the skilled technical workforce. It has several programs aimed at this segment of the workforce—I will describe two of these programs below:
The **Advanced Technological Education** (ATE) program is focused on two-year colleges and supports the education of technicians in high-technology fields. The program involves partnerships between academic institutions and industry to promote improvement in the education of science and engineering technicians at the undergraduate and secondary school levels. The ATE program particularly encourages proposals from Minority Serving Institutions. To date, ATE has awarded more than $950M total to 492 institutions.

ATE recently released a report of its impacts:[2]

- In 2014, ATE projects and centers developed 2,430 education materials, such as courses, lab experiments or other types of educational activity.
- Of the students participating in ATE programs during 2014, 91% either continued in their program or completed a program.
- ATE projects and centers have 3,890 collaborations with business and industry, and 90 ATE projects and centers offered 2,190 professional development activities attended by 45,830 educators.
- ATE projects have also been successful in broadening participation. Women have significant leadership roles in ATE with 24 of the 42 ATE centers having female principal investigators. According to a NSF-funded survey of ATE grantees, underrepresented minority students comprise 44% of all students in ATE-supported programs; this is about double the percentage of minority students in other STEM programs.

[2] https://www.atecenters.org/wp-content/uploads/PDF/ATEIMPACT_2016-17.pdf

In short, ATE does what NSF does best: it increases knowledge, catalyzes institutional change, and builds capacity.

CyberCorps – Scholarship for Service funds institutions of higher education to develop and enhance cybersecurity education programs and curricula; and to provide scholarships to undergraduate and graduate students in strong academic cybersecurity programs – an area of key strategic importance to U.S. national security. The students receiving scholarships must be U.S. citizens or lawful permanent residents and must be able to meet the eligibility and selection criteria for government employment. Students can be supported on these scholarships for up to three years, and in return, they agree to take government cybersecurity positions for the same duration as their scholarships. The program also requires a summer internship at a Federal agency. Government agencies eligible for job placement include Federal, state, local, and tribal governments.

It is true that the bulk of NSF's investments go towards the conduct of basic research, the central tenet of NSF's mission is to promote the progress of science. While community colleges are eligible for most NSF awards, research is not the primary mission of community colleges and technical schools. During the NSB's listening session at Baton Rouge Community College, we heard time and time again that community college faculty lack the institutional support and capacity to apply successfully for NSF research grants. The biggest hurdle is their teaching load, which may require them to teach up to eight courses per semester or quarter. Therefore, it is not surprising that the majority of NSF research dollars go to research universities and students at bachelor's and graduate degree levels.

That said, basic research funding awarded to research universities may still benefit community colleges in multiple ways. For example, NSF funds basic research in STEM education broadly, and addresses fundamental questions such as, how to teach STEM more effectively, how students of all ages and demographic groups learn in different settings; and how to increase interest and retention in STEM. All of this knowledge can benefit educators and students in K-12 and at the community college level. Additionally, NSF grantees at four-year colleges and universities can (and have) formed partnerships with community colleges to offer community college students authentic, high-quality research experiences.

For its part, the National Science Board recognizes the importance of the skilled technical workforce both to creating economic opportunity for all Americans and to our National competitiveness. In November 2017 we established the Task Force on the Skilled Technical Workforce, which I chair. The charge to the Task Force is appended to my written testimony. Briefly, the Task Force is engaging with skilled technical workforce stakeholders to explore the opportunities and challenges they face and identify ways that NSF and the NSB can help.

Should NSF provide more funding to support STEM education at community colleges?

Answer: To fulfill its mission, NSF always needs to adapt to changes in the STEM research, education, and workforce landscape. We set priorities within our portfolio based on extensive community input, national priorities, including those identified by Congress and the Administration, and emerging opportunities. The Board looks at these questions as part of the annual budget process, and it's challenging in the context of flat budgets – an addition to STEM at community colleges could mean a subtraction somewhere else. One of the questions the Task Force on the Skilled Technical Workforce is addressing is how NSF and NSB can best support this segment of the workforce.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mentoring, Training, and Apprenticeships for STEM Education and Careers"

Dr. Victor R. McCrary, Vice Chancellor for Research, University of Tennessee, Knoxville; Member, National Science Board and Chair, Task Force on the Skilled Technical Workforce

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. *On behalf of STEM Scholar Claire*: As a FIRST student and STEM scholar, I am privileged to visit companies that are enthusiastic about paying for student education because they see it as training future employees. How do you believe we could partner with such companies, or make that information more well-known?

   Answer: We all have a responsibility and a role to play. Internships, coops, apprenticeships, and tuition assistance programs are investments in the workforce of the future. Cross-sector partnerships among companies, government agencies, non-profits, and higher education is one way of ensuring that these programs are sustainable and widely available to all.

   Organizations like the National Science Board are raising awareness of these programs through their outreach efforts to students, educators, businesses, and policymakers, such as Congress and the Administration. The NSB recent created a Task Force on the Skilled Technical Workforce to explore how NSF and the NSB can help. At the first meeting of the Task Force in February, we learned about the Grow with Google program, a suite of free training programs and tools to help students and employers grow their skills, careers, and businesses.[3] The Task Force has also engaged in "listening sessions" to learn more about community needs and ways of connecting students with employment opportunities. The Board plans to hold listening sessions later this year at Macomb Community College near Detroit, MI, and possibly in South Carolina and Tennessee.

   NSF supports collaborative projects involving academic institutions, private industry, and state and local governments. The Foundation also works closely with other Federal agencies in cross-cutting areas of research and education, and we support U.S. participation in international scientific efforts. Promoting partnerships is one of our core strategies. Collaboration and partnerships between disciplines and institutions and among academe, industry, and government enable the movement of people, ideas, and tools throughout the public and private sectors.[4]

[3] You can watch the NSB Task Force discussion with representatives from Grow with Google here: http://www.tvworldwide.com/events/nsf/180221/default.cfm (free registration required).
[4] Read more about NSF partnerships here: https://www.nsf.gov/about/partners/

Students also must take an active role in seeking out opportunities. I would suggest that you and other interested students work with Dean Kamen's national FIRST organization, but also work with your local companies in the region early in the planning process. FIRST Robotics teams have successfully engaged the local industry by either approaching them directly, or going through the local chamber of commerce. Companies see the value of engaging the students early, so go to them and be a part of establishing those connections. In addition, there are LEGO® Leagues in many regions across the country which engage STEM-curious K-12 students.

2. *On behalf of STEM Scholar Claire*: How could robotics programs like FIRST be more broadly offered in high schools? What role could STEM mentors play in outreach for these types of school programs?

   Answer: FIRST robotics is a long-standing program, established in 1989. As a result of almost 30 years of work, the program is present all over the world, has reached over 515,000 students total so far, and is sponsored by over 20+ large companies from regional industries. There are also regional support systems in place for every state to help a teacher bring FIRST to their classroom. It takes a significant amount of work, human capital, partnerships, and funding to make a program as successful and widespread as FIRST. The FIRST program certainly provides a successful model that new STEM programs may choose to consider while developing capacity.

   Beyond strengthening and building upon the already existing strategies that makes FIRST successful, the program could engage directly with the Board of Education for each school locality. Boards of Education are the gatekeepers of each school district, and persuading them on the value-added will go a long way towards adoption and buy-in. STEM mentors are also critical in providing outreach for these programs. Many programs, such as FIRST, can be established in schools via the motivation of a single school teacher. Each STEM mentor has a network, and the power of communicating the importance of STEM programs within each mentor network can go a long way in building the program's capacity.

3. *On behalf of STEM Scholar Nathan*: Technology is constantly expanding horizons in so many areas, occasionally pushing the boundaries of ethical principles. How can apprenticeships educate STEM students and mentees on this evolving issue?

   Answer: The technology-ethics interface touches our everyday lives as we use Facebook, Google, location services on our smartphone, wearable devices that provide data on our physiological statuses, genetic testing and mapping of our genomes (e.g., ancestry.com, 23andMe.com), and much more. It is important for our entire citizenry to be cognizant of ethical concerns spurred by existing and emerging technologies. Four-year institutions have already developed many ethics programs that span bioethics, business and

professional ethics, medical ethics, environmental ethics, and research and scientific ethics. The universities have the infrastructure and do deliver on conversations that explore the issues related to the technology-ethics interface.

One strategy would be for apprenticeship-offering institutions to partner with four-year institutions with already existing ethics programs. Faculty members from the universities could give lectures to the students in apprenticeship programs. The conversation should not be confined to specific technologies, but rather should address ethics in general, including the notion of social justice and job displacement by technology. It is important to note that many apprenticeship programs have a professional skills component, and these ethics lectures would complement the student-learning.

Universities are not the only avenue for training students on technology-ethics issues. Apprenticeship programs are often linked with industry and therefore can tie into pre-existing programs designed for a companies' workforce. It is also possible for professional organizations linked with a specific technology to develop guidelines and a professional code of ethics. For example, in October 2016, the White House issued a statement in a report on Artificial Intelligence calling on professional organizations "to update (or create) professional codes of ethics that better reflect the complexity of deploying AI and automated systems within social and economic domains." Developed professional code of ethics for specific types of technologies can be utilized by related apprenticeship programs.

Federal agencies also have ethics programs that can be used as a model for apprenticeship programs. For example, the National Institutes of Health (NIH) has research and scientific ethics courses for post-bacs, graduate students, postdocs, and ethics mentors.[5] These programs may serve as a model for program delivery, curriculum content, and learning assessment.

4. *On behalf of STEM Scholar Jessica:* What programs could be developed within the public school system to increase STEM outreach for all students, and not just the limited few who are accepted into these types of programs?

   Answer: S&T has permeated nearly all facets of our daily lives. The workplace is no exception. More and more jobs require at least some STEM know-how, not just "STEM jobs." People in jobs as ranging from auto mechanics, to financial analysts, farmers, and health care technicians will all need at least some technical expertise. Therefore, it is critical that all students from all backgrounds are "STEM-capable." We need to get the message out to students, parents, counsellors, principals and teachers that STEM is not just for "scientists."

[5] https://www.training.nih.gov/ethics_training_home_page.

The Federal government's role in the K-12 public school system in the United States is limited. However, there are things that Federal government can and should do.

- First, the Federal government can help increase awareness of evidence-backed programs that already exist. For example, the Department of Education's Institute of Education Sciences created and maintains the "What Works Clearinghouse."[6]

- Second, Federal agencies fund research into STEM pedagogy and learning that can help educators at all levels teach STEM more effectively. For example, NSF's Discovery Research PreK-12 program (DRK-12) makes investments aimed at enhancing the learning and teaching of STEM by preK-12 students and teachers, through research and development of STEM education innovations and approaches.

- Third, NSF investments have led to the creation of materials that public-school teachers use in the classroom. For example, NSF's Innovative Technology Experiences for Students and Teachers (ITEST) program supports the research and development of innovative models for engaging K-12 students in authentic experiences that build their capacity to participate in STEM. You can learn about ITEST and what is has produced at the STELAR website: http://stelar.edc.org/projects.

- The majority of NSF's nearly 7-billion-dollar budget goes towards advancing scientific discoveries and educating and training our future scientists and engineers at colleges and universities in the United States. So you might ask, "How can that help students like me engage with STEM in elementary, middle, and high school?" In addition to the specific programs I mentioned above, all NSF grants must satisfy a "broader impacts" criterion. It is not enough for a research project to advance scientific understanding; it must also improve or address societal needs. One way university researchers could satisfy NSF's broader impacts criterion is by creating partnerships with public schools to engage in authentic research experiences and meet with practicing scientists and engineers.

  At the local level, I would encourage schools to bring back chemistry labs, bring back shop, bring back electronics—all of these areas coupled with advances in information technology and electronics—would help greatly in engaging students at all levels with authentic STEM experiences. My last suggestion would be for schools and students to engage in discussions about career opportunities and trends starting in 9th grade or even earlier!

[6] https://ies.ed.gov/ncee/wwc/

5. *On behalf of STEM Scholar Taylor*: Would you be willing to take on a mentee if they contacted you? If so, how many mentees would you be willing to take on?

   Answer: Yes, and I would take on 2-3 students here who would be interested in either non-degree or degree STEM-capable careers. One critical component would be for mentees to learn early we all have a responsibility to take what we have learned to assist others – "we vs. me." Our Nation and the world's future depends on focusing on the accumulation of knowledge for the sake of the planet vs. the accumulation of wealth. That's how we roll forward!

   a. Do you believe that internships, mentoring, and apprenticeships are just as valuable for the mentor as the mentee?

      Answer: Yes, because we are life-long, continuous learners. Students I hired and mentored at the National Institute of Standards and Technology (NIST) in the late 1990s keep in touch with me and discuss their careers, their companies, and new technologies and approaches. It is exciting and keeps me connected and keeps me on top of new innovations. It also keeps me young in mind and spirit! Even at this point in my career, I still have mentors who offer guidance and advice. Both young and old, they get as much joy out counseling me and knowing you can still "teach an old dog new tricks!"

Responses by Dr. John Sands

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mentoring, Training, and Apprenticeships for STEM Education and Careers"

Dr. John Sands, Department Chair, Computer Integrated Technologies, Moraine Valley Community College; Director and Principal Investigator, Center for Systems Security and Information Assurance

Questions submitted by Ranking Member Daniel Lipinski, House Committee on Science, Space, and Technology

1. Existing regulations for apprenticeships require registered apprenticeship program sponsors to provide equal opportunity for participation and to protect their apprentices from discrimination. Despite these regulations, women and underrepresented minorities continue to face significant barriers to equitable participation in apprenticeship programs. Women make up about half of the labor force, but only seven percent of apprentices. Moreover, women and apprentices from minority groups tend to be concentrated in apprenticeships for lower-paying occupations. Why is it important that everyone have access to the full range of apprenticeship programs?

    a. What do you believe to be the major barriers to equitable participation in apprenticeship programs by women and minorities?

    Answer: From my experience, there are two major barriers to equitable participation in apprenticeship programs by women in minorities. The first is cultural. Academic institutions and businesses need to reframe the way they promote, describe and recruit apprentices. Many of the practices used by companies have an origin in older, traditional trades and don't represent the type of work and atmosphere the new technical workforce presents. Women and minority applicants need greater opportunity to explore these occupations that provide greater opportunity for higher incomes. Schools also need to link potential apprentices with current women and minorities that work in these environments so they can share their positive experiences and opportunities that they have been able to take advantage of.

    The second major barrier for women in minorities are career awareness and career pathways knowledge. Our educational system needs to do a better job of exposing students in the K-12 system to these opportunities and specifically pathways that enable students to focus on these careers earlier in their academic programs.

b. How can apprenticeship sponsors and educational institutions improve their recruitment strategies to ensure equal opportunity?

Answer: Apprenticeship program sponsors in academia need to invest in better programs to increase student awareness and better educate career counselors and academic advisors on the opportunities these new technical jobs provide. The use of cohorts and mentors have proven to increase minority and female participation in these programs.

2. In your testimony you bring up the point that successful examples of apprenticeship programs in Europe and Asia are efficient at meeting workforce demand, but have resulted in older citizens being denied access to apprenticeship opportunities. How can American apprenticeship programs avoid creating the same disadvantages for mid- and late-career workers?

Answer: The key to preventing apprenticeship programs from excluding older workers is to build apprenticeship programs that have multiple pathways and to promote these pathways and the benefits each pathway provides to the employer, the workforce in general and participating students. For example, returning older workers typically bring work experiences that students coming from just an educational program may not possess. Most organizations also benefit from having a diverse workforce including diversity in the age of their apprentices. We work with several employers that are experiencing the result of not diversifying the age of their applicants. Several of the local manufacturers are struggling with losing the majority of their highly technical workforce that are eligible for retirement. These companies fail to plan for having younger participants join the organization and who have the ability to work alongside and learn from the older and more experienced employees.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mentoring, Training, and Apprenticeships for STEM Education and Careers"

Dr. John Sands, Department Chair, Computer Integrated Technologies, Moraine Valley Community College; Director and Principal Investigator, Center for Systems Security and Information Assurance

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. *On behalf of STEM Scholar Claire*: As a FIRST student and STEM scholar, I am privileged to visit companies that are enthusiastic about paying for student education because they see it as training future employees. How do you believe we could partner with such companies, or make that information more well-known?

   Answer: Academia needs to do a better job of building partnerships between the faculty in our classrooms, the career counselors, the academic advisors and representatives from our local employers. Too often, the career and technical programs in our institutions struggle to gain the type of promotion and support that high profile programs like nursing or other professions within the health services areas receive. The health service programs also benefit from a highly established and regulated workforce pathway. These pathways which include required clinical experiences have resulted in very strong partnerships between our academic programs and the local health care providers. These partnerships should serve as a model of how to build stronger apprenticeship programs in our career and technical fields.

2. *On behalf of STEM Scholar Claire*: My peers do not have the same opportunities to visit manufacturing centers like I have through STEM scholars and FIRST. How can we change that? What could high schools and colleges do to bridge that gap?

   Answer: These types of events should be promoted and built into the academic schedule. For example, many school districts schedule a manufacturing or cybersecurity day. These special scheduled days are used to bring professionals from manufacturing or cybersecurity to the campus to engage students and promote these occupations. These events can also include scheduled visits to local employers so students can experience different workforce environments.

3. *On behalf of STEM Scholar Jessica*: Some of my classes have tried to conduct a STEM-related project in the classroom, yet my peers and I felt rushed and confused, and often feel that teacher does not know how to explain the material well. Can programs like these help teachers develop a STEM-related lesson that is beneficial to both students and teachers?

   Answer: There are several good examples where leading organizations have been funded to build relevant STEM related exercises for the benefit of students from STEM programs. One example would be a project lead by the Center for Occupational Research and Development (CORD). This group received funding from the National Science Foundation to develop a series of projects entitled Necessary Skills Now, designed to engage students and promote skills in two target STEM areas. These activities are freely available to institutions and CORD has offered faculty development workshops to increase faculty knowledge and effectiveness in using these activities in their classrooms.

4. *On behalf of STEM Scholar Taylor*: Would you be willing to take on a mentee if they contacted you? If so, how many mentees would you be willing to take on?

   Answer: Moraine Valley Community College has established programs of providing mentees for current students. These programs include a Women in Technology group that matches current women that work in the STEM related fields with students studying in a current STEM program. It is my opinion that students would have a greater benefit from a mentor from a local business or employer than a faculty member. These employers have the resources to provide students with visits to their facilities and inside prospective on how students can prepare for the apprenticeship experiences that best fit their career aspirations. I would like to say that faculty members are always available for academic and career advising and to connect students with organizations that provide the mentorship they are seeking.

   a. Do you believe that internships, mentoring, and apprenticeships are just as valuable for the mentor as the mentee?

      Answer: With the growing shortage of STEM related workers in our workforce, internships and apprenticeships can be an extremely valuable tool for the mentees to identify new talent and develop future employees. In talking to most employers, the lack or shortage of talented new employees is one of their greatest challenges and ultimately affects their bottom line.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Innovations in STEM Mentoring, Training, and Apprenticeships"

Dr. John Sands, Department Chair, Computer Integrated Technologies, Moraine Valley Community College; Director and Principal Investigator, Center for Systems Security and Information Assurance

Questions submitted by Representative Jacky Rosen, House Committee on Science, Space, and Technology

1. In your testimony you describe several barriers to providing job-related training to cybersecurity workers, including difficulty establishing effective apprenticeship programs. Cybersecurity is a top concern here in Congress, and especially for my constituents in Nevada, where tech companies like Switch are at the forefront of cybersecurity defense. We are continuing to see a huge demand for cybersecurity professionals, and we need to ensure we have enough trained workers in place to respond to security threats.

    a. Can you elaborate on the difficulties of expanding apprenticeships, specifically in the cybersecurity sector?

    Answer: The cybersecurity sector poses several obstacles in developing effective internship or apprenticeship programs. These obstacles include the potential of exposing students to the critical information and operations of an organization. Companies need assurance that the individuals that they bring in to internship and apprenticeship programs are trustworthy and understand the criticality of the systems and data they are entrusted with. Funding programs that enable academic institutions to build more strenuous recruiting programs that are designed to increase student workforce skills and student trustworthiness could address this problem. Another barrier is the impact of the current shortage of cybersecurity professionals. This shortage has put a strain on organizations to take on additional responsibilities like operating an internship or apprenticeship program. Establishing programs that transfer more of these responsibilities to academic institutions like community colleges would relieve much of these burdens from the local employers.

b. What can the federal government do to assist states, schools, and industry with establishing or developing a cybersecurity apprenticeship program?

Answer: The funding of programs like the National Science Foundation ATE Program can have significant and wide scale impact on building a better national infrastructure for cybersecurity internships and apprenticeships. Many of the ATE programs fund institutions that provide leadership and support for community colleges across the nation struggling to meet the current and future STEM workforce shortage. Funding programs specifically designed to increase the nation's career pathways including apprenticeships and internships could have measurable impact on these programs. The ATE program targets schools and individuals interested in leading these types of efforts. Investment in these programs have a long list of achievements including the creation of multiple curriculum development and distribution centers, better understanding of workforce needs in critical STEM areas and more effective programs in addressing the knowledge and skills requirements of specific industries like cybersecurity. ATE solicitations specifically targeting the improvement and growth of cybersecurity internships and apprenticeships would garner significant interest and could have a relatively rapid impact on programs nationwide.

The National Security Agency and Department of Homeland Security recently established a program to improve the quality of cybersecurity programs across our nation. The NSA Centers of Academic Excellence have established curriculum standards, faculty requirements and other institutional criteria required of an effective cybersecurity program. This criteria should be expanded to address the creation and operation of effective apprenticeship programs for cybersecurity professionals. These two federal agencies currently have considerable influence on growing quality cybersecurity programs. Providing additional funding to these organizations seems like a very efficient way to have widespread impact in addressing the need for cybersecurity apprenticeship programs.

Responses by Mr. Montez King

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mentoring, Training, and Apprenticeships for STEM Education and Careers"

Mr. Montez King, Executive Director, The National Institute of Metalworking Skills

Questions submitted by Ranking Member Daniel Lipinski, House Committee on Science, Space, and Technology

1. Existing regulations for apprenticeships require registered apprenticeship program sponsors to provide equal opportunity for participation and to protect their apprentices from discrimination. Despite these regulations, women and underrepresented minorities continue to face significant barriers to equitable participation in apprenticeship programs. Women make up about half of the labor force, but only seven percent of apprentices. Moreover, women and apprentices from minority groups tend to be concentrated in apprenticeships for lower-paying occupations. Why is it important that everyone have access to the full range of apprenticeship programs?

    a. What do you believe to be the major barriers to equitable participation in apprenticeship programs by women and minorities?

    Answer: Equitable participation in apprenticeship programs by woman and minorities has historically been an issue within our country. Unfortunately for our nation, this issue continues to bottleneck upskilling our workforce to remain competitive globally. However, the causes of inequitable programs have shifted prejudices to awareness and mindsets:

        1. Awareness – As I travel our nation educating women and minorities about the world of skilled-based occupations and apprenticeships, I find that an overwhelming large majority are not even aware that such opportunities exist. The majority of my audiences are magnetized by the technologies and occupations and walk away wondering why these opportunities were not mentioned or described in the same prestige as I presented them.

        2. Educator and Parental Mindsets – Educator and parents are lacking knowledge of the wealth of career opportunities and earning potential through apprenticeable career paths. Consequently, our future workforce is pre-program to pursue traditional careers that hold high levels of prestige. This results in everyone competing for the same jobs, while not filling the majority of jobs that must be filled. In addition, educator and parents ignore or fail to take inventory interests of their students and kids. This results in too many students unemployed or underemployed with college debt. Students find out the hard way that "Cs" get degrees but they don't necessarily get jobs.

b. How can apprenticeship sponsors and educational institutions improve their recruitment strategies to ensure equal opportunity?

Answer: Apprenticeship sponsors and educational institutions can improve their recruitment strategies to achieve equality by Creating an Ecosystem for everyone. A significant portion of individuals that took advantage of apprenticeship programs discovered their careers through a family member (father, grandfather, uncle, etc…). These family members are typically not minorities. Ensuring equal opportunity requires equal awareness as well. The lucrative truths about these apprenticeship opportunities should be shared with every school in the nation and not be a hidden secret. The boundaries of the ecosystem should extend as early as middle school students of every classroom to career professional mentoring.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mentoring, Training, and Apprenticeships for STEM Education and Careers"

Mr. Montez King, Executive Director, The National Institute of Metalworking Skills

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. *On behalf of STEM Scholar Claire*: As a FIRST student and STEM scholar, I am privileged to visit companies that are enthusiastic about paying for student education because they see it as training future employees. How do you believe we could partner with such companies, or make that information more well-known?

   Answer: As the Executive Director of NIMS, I am honored with the opportunity to visit hundreds of companies each year. In fact, I am currently working with an employer that employs over 15,000 employers in on division. This company pays for student education because they understand that having a skilled workforce is to their advantage. Many companies hesitate to invest in paying for student education in fear of losing those workers to competitors. This employer understand that more skilled people is the workplace is better for everyone and positively impacts their supply chain capabilities and capacity. Conclusively, the ROI on such an investment must be clearly communicated at a national level to launch a movement.

2. *On behalf of STEM Scholar Claire*: How can we strengthen the connection between companies offering STEM-related internships and apprenticeships and potential applicants?

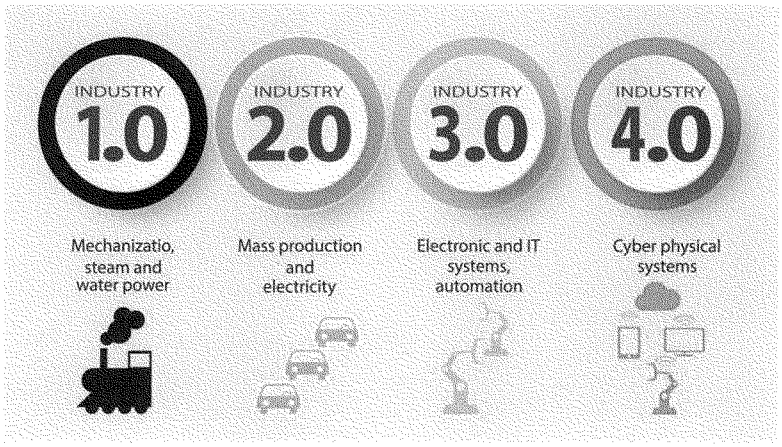
   Answer: The connection between companies offering STEM-related internships and apprenticeships and potential candidates can be strengthened by companies and educational institutes campaigning at the middle school level. Only 16 percent of American high school seniors are proficient in mathematics and interested in a STEM career.[1] Campaigning and education about technologies and jobs of the future must start early to mitigate the lack of interest.

3. *On behalf of STEM Scholar Nathan*: Technology is constantly expanding horizons in so many areas, occasionally pushing the boundaries of ethical principles. How can apprenticeships educate STEM students and mentees on this evolving issue?

   Answer: NIMS is currently in talks about developing Industry 4.0 (i4.0) standards and credentials. i4.0 is the next industrial revolution. These standards and credentials are the

[1] U.S. Department of Education: https://www.ed.gov/sites/default/files/stem-overview.pdf

seeds that must be planted today in order for us to harvest the needed talent for the jobs of tomorrow and remain globally competitive. Any students with a STEM related career track should be credentialed is these technologies. I am available for a full presentation should you desire.



4. *On behalf of STEM Scholar Jessica*: Many of my peers and friends think STEM is meant for "smart" kids, when STEM should be for everyone. How can students that have no exposure to STEM succeed in STEM programs?

   Answer: Students that have no exposure to STEM or believe it stands for "smarts kids" must be educated on the multitude of career opportunities. For example, our best mechanical engineers are those that first worked as machinists. A machinist career is not inherent to STEM careers by most educators but the two careers complement each other. The recommended solution is to create a stackable and portable model the enables students to focus where their interests and abilities take them. Most importantly, the prestige of either career should be revered the same. Why not? The both are equally important and extremely lucrative.

5. *On behalf of STEM Scholar Taylor*: Would you be willing to take on a mentee if they contacted you? If so, how many mentees would you be willing to take on?

   a. Do you believe that internships, mentoring, and apprenticeships are just as valuable for the mentor as the mentee?

      Answer: I am always willing to take on a mentee. My life was turned in the right direction by my mentor at an early age. I keep a portfolio of hundreds of my

mentees over the years. My success with helping others stem from my experience as a mentor. Please view the following video about my life as a mentee and mentor: https://youtu.be/5wp4s91kVrs.

Responses by Dr. John Bardo

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mentoring, Training, and Apprenticeships for STEM Education and Careers"

Dr. John W. Bardo, President, Wichita State University

Questions submitted by Ranking Member Daniel Lipinski, House Committee on Science, Space, and Technology

1. Existing regulations for apprenticeships require registered apprenticeship program sponsors to provide equal opportunity for participation and to protect their apprentices from discrimination. Despite these regulations, women and underrepresented minorities continue to face significant barriers to equitable participation in apprenticeship programs. Women make up about half of the labor force, but only seven percent of apprentices. Moreover, women and apprentices from minority groups tend to be concentrated in apprenticeships for lower-paying occupations. Why is it important that everyone have access to the full range of apprenticeship programs?

   Answer: The workforce of the future needs to be (and is going to be) more diverse. In an increasingly globally competitive market, it makes no sense from a national policy perspective, a community-regional development perspective, or from the perspective of the individual, to limit access to education and training that is sorely needed if the U.S. is to remain competitive. Any other approach will limit American competitiveness unnecessarily.

   a. What do you believe to be the major barriers to equitable participation in apprenticeship programs by women and minorities?

      Answer: There are many issues here. Some involve the individual who may not understand the importance of these types of programs. There also are still differences in choices of majors within universities that affect the availability of apprenticeships. Finally, there are cultural differences within employers. In all three cases, better communication and preparation are critical if we wish to increase participation. In our experience, the outside organizations with which we are working seem to be increasingly seeking diversity both as an organizational value and as a reality of the changing nature of the workforce.

b. How can apprenticeship sponsors and educational institutions improve their recruitment strategies to ensure equal opportunity?

Answer: We have shifted significantly how we recruit students to the university and as a result we have seen a major increase in "under-represented minorities," students who haven't traditionally had access to higher education. We are moving scholarship funds to increase the number of need-based institutional awards to encourage low-income residents to apply and attend college. Finally, we have formed a division focused on community development to reach out and be more involved in low-income neighborhoods in our region.

A major part of our recruitment effort is to emphasize applied learning, so internship/apprenticeship opportunities are increasingly key parts of our strategic positioning as an institution. This approach provides additional information to large numbers of potential students, especially in Kansas, Oklahoma, Texas, and Missouri, our key recruiting region.

One of the most critical questions involves that changing nature of the workforce. Many employers already understand this and are taking action. Most issues may well involve the individual student and his or her belief that such education is appropriate and that he or she is capable of achieving in this area.

If STEM workforce is to be a major federal focus, then there also needs to be a comprehensive policy regarding K-12 support. This might involve funding, a center for best practices and coordination with the many NGOs that are concerned with this issue. From living with this daily, there is much effort by many people, but things feel uncoordinated and unfocused. The same can be said for efforts to encourage experiential learning and applied research at the university level. My long testimony makes some suggestions as to how these areas might be improved.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mentoring, Training, and Apprenticeships for STEM Education and Careers"

Dr. John W. Bardo, President, Wichita State University

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. *On behalf of STEM Scholar Claire*: As a FIRST student and STEM scholar, I am privileged to visit companies that are enthusiastic about paying for student education because they see it as training future employees. How do you believe we could partner with such companies, or make that information more well-known?

   Answer: While companies tend to be enthusiastic, they also have experienced problems with training and performance. This limits both their actual willingness to work with interns and the interns' quality of experience. WSU is experimenting with a model in which we act as the facilitator between the company and the student. The company pays us to pre-train the student and, if the student doesn't work out, to manage the out-placement of that student. This gives the university a stake in the student's performance, provides better apprentices/interns, and seems to (at least initially) be associated with student success.

2. *On behalf of STEM Scholar Claire*: Could college students mentor high school students as part of their education? What about having high school students in STEM classes mentor middle school students?

   Answer: That is an ongoing process at many universities, including WSU. We offer a wide range of programs, including some through the federal TRIO programs, to support potential STEM students. We would love for the local school district to construct a STEM magnet school next to the university. We know that we tend to disproportionately lose girls and minorities from STEM fields in middle school and that a greater immersion in the campus might well make a huge difference. Mentoring would be enhanced, but so too would be regular access to our maker's space, labs, and STEM businesses that are locating on the campus. This is more of an emersion process than just a mentoring program.

3. *On behalf of STEM Scholar Nathan*: Can mentors help STEM students improve communication skills in both personal and workplace relationships? In addition to those applicable in the workplace, what other skillsets do you believe a mentor could teach a mentee?

   Answer: Many STEM students leave universities with a great technical education but they have not necessarily had the opportunity to apply those lessons adequately. That has not been the historical focus of universities. Mentoring in a real workspace on real projects can provide that experience, but it is going to be important that the mentor be prepared to work with the student on these issues. So, the company will either have to prepare the mentor or contract for outside assistance. That is one reason that we are experimenting with being the coordinating entity for mentoring.

4. *On behalf of STEM Scholar Taylor*: Would you be willing to take on a mentee if they contacted you? If so, how many mentees would you be willing to take on?

   Answer: Possibly. Given the things that we discuss at my level, it is difficult to include a junior mentee since many of the issues are covered by personnel law or otherwise are not subject to discussion in front of outside individuals. The American Council on Education has a program that places individuals with college presidents in a mentoring relationship. Given the intensity of the issues dealt with, ACE normally limits the number to a single individual working with a president.

   That said, I have mentored a number of individuals who wanted to become college administrators and I'm working with one now. The model is more difficult because of the issues raised above, but I am involving her as much as possible and encouraging her to talk through issues she might face in a new role.

   a. Do you believe that internships, mentoring, and apprenticeships are just as valuable for the mentor as the mentee?

      Answer: I have always found it so. I've never worked with a mentee where I did not learn something and I have always found the situation very personally and professionally satisfying. In fact, my first mentee has remained a very close personal friend for more than 40 years.

      What we are seeing in technical fields is that the personal relationship is important to the mentor but sometimes students have access to new information that also helps the mentor. We have seen several cases of "reverse mentoring," which tends to create a good relationship among the parties if it is done well.

It is important to understand that mentoring is not a simple job and it requires some work on the part of the organization to work with employees who will be mentors. Simply putting two people together does not ensure a good mentoring relationship. There needs to be mentor training and supervision within the organization if one is to expect a good outcome.